Exploring an implementation framework for building information modelling to support sustainable development in the Lebanese construction industry
a qualitative approach

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Exploring an Implementation Framework for Building Information Modelling to Support Sustainable Development in the Lebanese Construction Industry: A Qualitative Approach

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Abstract

Building Information Modelling for Sustainable Development in Lebanon has been identified as a growing and revolutionary tool capable of improving the performance of the construction sector. With a growing population and overurbanization, there is an increasing demand for construction projects in Lebanon, thus hindering the environment and consuming natural resources. The Lebanese construction sector has been neglecting the importance of sustainable development; however, this research adopts a qualitative approach to explore the influence of implementing Building Information Modelling in the Lebanese construction industry to support sustainable development. The aim of this research is to develop a theoretical framework for the successful implementation of BIM by examining the barriers limiting BIM implementation in terms of economic, social, and environmental sustainability also referred to as sustainability pillar. Interviews were carried out with construction professionals in Lebanon to understand the definition, benefits, barriers, and current sustainable performance to further examine the implementation of BIM. The proposed theoretical framework is divided into seven components that will unlock the possibility of implementing BIM in the Lebanese construction industry to achieve sustainable growth. The results demonstrated that the implementation of BIM for Sustainable Development is achievable by identifying the main barriers of economic, social, and environmental sustainability which will be incorporated in the existing standards and technologies of BIM. The validity of the proposed theoretical framework was examined by the Lebanese construction industry and instituted the direction for future research.

Keywords

Building Information Modelling (BIM); Architecture Engineering and Construction (AEC); Lebanese construction; Sustainable Development; Sustainability pillars.

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Chapter I: Introduction

1.1 Chapter Overview

The following chapter is a brief introduction for this Ph.D. research, in which the main ideas and subject issues will be briefly discussed. This chapter will establish the basic principles of Building Information Modelling (BIM) and draw attention to its impact on sustainable development. Moreover, this chapter will highlight the current major issues facing the Lebanese construction industry, as well as, identify the gaps in knowledge contributing to this research. In addition, this chapter will clearly state the aim and objectives behind this research and present a brief look at the proposed methodology. Finally, this chapter will serve as a guide through the content of this research paper.

1.2 General Introduction

Widely criticized as a fragmented industry, the architecture, engineering, and construction (AEC) industry has been on the receiving end of many adverse comments questioning its poor quality, lack of collaboration, and disregard for innovation. By investigating the relationship between design management, innovation, and the role of BIM, Elmualim and Gilder (2014) emphasized on the desperate need for a change in the construction industry. Evidently, Building Information Modelling (BIM) presents the opportunity to elevate innovation in the AEC industry. BIM has been defined as the process of creating and managing building data through three-dimensional (3D) visualization and real-time dynamic building modelling (Eastman et al. 2013). In their research, Elmualim and Gilder (2014) conducted a questionnaire survey investigating whether people consider BIM as an innovative tool capable of improving the AEC industry, or whether BIM is not capable for reaching such expectation. As a result, 63% of respondents believe that BIM will significantly improve the overall construction practice. However, many reasons still hold the successful implementation of BIM, such as lack of capital investment, of which 20% of respondents seem to have this problem, 15% responded by saying that the benefits of BIM do not outweigh its cost, and finally, 37.8% of respondents did not seem to be interested and have no reason for implementing BIM themselves. Unfortunately, this way of thinking has set the AEC industry on a path of severe consequence.

An example that elaborates these consequences is the heavy consumption of natural resources and raw material to supply the rising demand for construction projects, which has placed a substantially large pressure on today's environment. Hurlimann et al. (2018) highlighted that the AEC industry has limited control over the negative environmental impacts it is responsible for, mainly because of its position in the building supply chain. The AEC industry is responsible for construction; however, another industry is responsible for the operation, therefore the AEC industry sets a short-term plan to minimize risk and maximize profit, thus neglecting its impact on the environment. As a result, the AEC industry has been a major contributor for significant environmental pollution and resource exploitation, even though sustainable construction has been receiving positive attention and aspiration, yet it still requires major performance changes (Yin et al. 2018).

Building Information Modelling has presented itself as a repository capable of narrowing fragmentations between building delivery professionals and aid in improving the outcome of any construction project (Fadeyi 2017). Furthermore, the growing interest in BIM shown by the rising number of academic research and journal publications over the past years highlights the key role BIM is undergoing to deliver a better sustainable value (Chong et al. 2017). Several developed countries, such as the UK and the US, have realized the importance of sustainable development and the negative environmental consequence resulting from the AEC industry. For that reason, these developed countries have taken initiative to develop the Framework for Sustainable Strategic Development promoting the importance of using new technology, such as BIM, and its development through new university program courses, as well as, BIM association for better sustainable practice such as modular coordination, material substitution, and reduced demolition (Alwan et al. 2017). Nevertheless, there are many barriers that remain unsolved and hinder the proper implementation of BIM, especially in developing countries (Chan et al. 2019).

When dealing with sustainability, there are many factors that need to harmonize to achieve true sustainability such as social, economic, and environmental sustainability also known as the sustainability pillars (Fischer et al. 2017). Each sustainability pillar presents its own benefits and challenges; therefore, it is necessary to uncover possible

BIM tools to further enhance each of the sustainability pillars. The result will prompt sustainable development in the AEC industry with the aid of Building Information Modelling.

1.3 Statement of Research Problem

The rapid development of society and technology is deteriorating the environment. The AEC industry is a major contributor to many negative impacts on the environment. Lebanon, a developing country, is witnessing improvement in its economic activity compared to previous years. Unfortunately, rising economic activity in a country heavily dependent on the construction sector usually implies more construction projects (Majdalani et al. 2006). Since Lebanon has low awareness of sustainability, rising population and construction activity will result in more negative environmental impacts on already existing problems. As a result, the implementation of BIM in developing countries such as Lebanon, still face many challenges to improve social, economic, and environmental sustainability. The relation between BIM and sustainable development remains unclear, even though, the subject has received tremendous attention and expanding research, many issues remain unsolved such as weak interoperability between BIM applications, lack of support in the construction and operation phases of the project life-cycle, lack of industry standards, low industrial acceptance, and unclear project delivery method (Lu et al. 2017).

According to Gerges et al. (2017), BIM adoption and implementation in Lebanon is relatively low. Only 7 companies in Lebanon responded to have been involved in construction projects using BIM, contributing to a total of 2% involvement. As a result, the study shows that Lebanon is one of the lowest BIM users in the Middle East. Over the past decade in Lebanon, BIM is being used as a tool for 3D visualization, clash detection, and quantity surveying (Awwad and Ammoury 2013). Lebanon has yet to scratch the surface of BIM's potential in elevating the construction industry. The reluctance to change the construction process has had a significant impact on Lebanon's sustainable performance, thus, sustainable construction in Lebanon is considerably primitive compared to the surrounding region (Srour et al. 2010). The low awareness levels on the

importance of sustainable development, as well as, the low implementation rate of BIM has created many complications for the Lebanese AEC industry.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this research is to develop a theoretical framework for the successful implementation of Building Information Modelling (BIM) and explore its impact on Sustainable Development in the Lebanese construction industry.

1.4.2 Objectives

Working towards properly achieving the aim of this research, there are several supplementary objectives that need to be examined accordingly. The objectives behind this research are:

- Identify the major contributors of the Lebanese construction sector prompting the need for sustainable development and analyse their sustainable impact.
- Examine different BIM attributes and their limitations that can be used as tools in sustainable construction.
- Explore the Critical Success Factors of BIM that impact social, economic, and environmental sustainability.
- Develop a framework for the successful implementation of BIM in the Lebanese construction industry.
- Validate the BIM framework and its impact on sustainable construction.

1.5 Research Questions

Inspired from the background research and the introductory statement, several questions come to light concerning the role of Building Information Modelling (BIM) in Sustainable Development, which promotes the aim and objectives behind this research. Questions such as:

- What role does BIM play in the Lebanese construction industry today, and how revolutionary is it considered to be in sustainable development?
- How does BIM adoption impact social, economic, and environmental sustainability in Lebanon?

- What are the barriers and limitations preventing the successful implementation of BIM in Lebanon?
- What are the critical success factors that need to be considered when developing a framework for the successful implementation of BIM in the Lebanese construction sector?

1.6 Research Motivation

The concept of BIM and the use of models instead of 2D drawings is not new, on the contrary, it has been existing for some time now, and as developed countries are adopting the use of BIM in the construction industry, Lebanon has been overlooking this technology. BIM is developing globally, whether, in terms of research or practice, the use of ICT and BIM in the construction sector has been increasing significantly and is becoming a mandatory application. As a result, BIM adoption has witnessed a steep rise in the US, from 28% in 2007 to 71% in 2012, similarly, in the UK, where BIM has become a government mandate in the public sector project. Furthermore, countries in West Europe, such as Germany, France, and Denmark have all increased there BIM adoption, in addition to countries in East Asia such as Japan, South Korea, and China have also seen a rise in BIM adoption rates. Even in the Middle East region, developed countries such as the UAE and Qatar have witnessed a rapid increase in BIM implementation, while countries such as Jordan and Lebanon still lag behind (Matarneh and Hamed 2017).

With BIM being recognized as a tool, the Lebanese construction sector should try and set new goals for its performance, primarily objectives that linked with sustainable development. Standards such as the ARZ building rating system aim to push the green building initiative and achieve better sustainable outcomes. At this point, the Lebanese construction sector stands at a critical decision, whether or not BIM implementation could be the nexus to achieve the desired aim of an enhanced sustainable performance in the Lebanese construction industry.

Based on the fact that Lebanon is in desperate need for a change, and that BIM could be the tool to aid in achieving the next goal, this researched was inspired in an aim to develop a roadmap that will facilitate the implementation of BIM in the construction industry, and will eventually help the sector to achieve a more sustainable outcome.

1.7 Methodology

The research methodology will introduce the adopted approach this research will follow. An extensive literature review was carried out using a range of information collected from books and peer-reviewed journals from libraries and internet-based sources. The literature review examines the negative environmental impact that resulted from a lack of sustainable construction and limited BIM implementation in the Lebanese AEC industry. As well as, the barriers and limitation challenging successful BIM implementation. After identifying the key issues disclosed in the literature, qualitative research was selected to build up to three case studies, where every case study will be based on semi-structured interviews with BIM and sustainable development experts in the Lebanese AEC industry. Based on the data collected, the analysis technique will require the use of NVivo software to analyse and interpret the information gathered throughout the data collection process. The discussion will aim to relate the literature with the information gathered to finalize the outcome.

1.8 Research Guide

This section will present the content of every chapter and will serve as a guide throughout this research:

- Chapter 1 is a general introduction with background information for the study and the nature of the problem. It identifies the gap, as well as, present the aim and objectives, research method, and significance of the study.
- Chapter 2 will introduce Building Information Modelling the definition of the term, as well as, present the barriers and limitations preventing the implementation of BIM. This chapter will also introduce the concept of sustainable development and identify its importance in the construction industry. Finally, this chapter will explore previously developed frameworks that have explored the implementation of BIM and identify gaps and limitations, which will be later on used to develop the framework.
- Chapter 3 will introduce the Lebanese construction industry and assess its current performance in sustainable construction. This chapter will evaluate the

performance of the Lebanese AEC industry and identify the barriers preventing BIM implementation as well as sustainable growth.

- Chapter 4 will discuss the approach, philosophy, and method adopted for this research. The research methodology will highlight the process adopted to develop this research. As well as, justify the selection of the adopted methodology and discuss the process of data collection and analysis.
- Chapter 5 will introduce the participants who took part in the interview process for data collection. This chapter will present the findings based on three case studies used to identify the themes of this research. The case studies will be analysed using Nvivo software and the results will be used to create a framework for successful BIM implementation in sustainable construction in Lebanon.
- Chapter 6 will be the discussion chapter, where the information produced from this research will be compared with previous literature to check the validity and consistency in the information gathered and produced throughout this research.
- Chapter 7 will present the proposed theoretical framework and the rationality of choice. In addition, this chapter will validate the framework of successful BIM implementation in sustainable construction by conducting interviews with two companies to validating the components of the proposed theoretical framework.
- Chapter 8 will be the concluding chapter of this research. This chapter will answer the research questions, as well as, review the process of achieving the aim and objectives. The chapter will provide the outcome of this research in addition to the contribution to knowledge theoretically and practically. Finally, this chapter will present the limitations of this research, as well as, the direction for future research.

Chapter II: Building Information Modelling (BIM) and Sustainable Development

2.1 Chapter Overview

The following chapter will take a closer look at previously discussed research and literature, to highlight the relation between innovation and the construction industry. The background research will show how the AEC industry has negatively influenced the environment thus inspiring the need for sustainable development. As well as, introduce and define Building Information Modelling whilst exploring the barriers and limitations preventing BIM's successful implementation. Moreover, this chapter will define sustainable development in the construction industry and introduce the concept of the sustainability pillars and examine how BIM could play a role in their evolution. Finally, this chapter will discuss different frameworks developed for the proper implementation of BIM.

2.2 Background Research

The construction industry became aware of the concept regarding sustainable development from the ongoing threat of growing population and over-urbanization. The rapid economic growth galvanized the increasing demand for building construction. In general, buildings consume more than 30% of total global energy (Berardi 2017) and an immense amount of raw material, such as 70% of global timber (Nguyen et al. 2017). According to Alwan et al. (2017), in the UK, building construction, operation, and demolition consume 40% of the UK's total energy and is a large contributor to fossil fuel emissions. Approximately 380 million tons of material and resources are being consumed by the UK construction industry annually, generating over 100 million tons of waste per year, of which 13 million tons are considered as unused material. Supplying energy to the construction sector relies majorly on fossil fuels. The continuous consumption of fossil fuels to supply energy, fiercely increased carbon emissions from 280 ppm to 391 ppm in 2011, eventually rising over 400 ppm in 2014 (Yue et al. 2015). Confirmed by Berardi (2017), the research evaluated trends for population growth and fossil fuel consumption to predict future patterns. By comparing the industry, transport, and building sector in several countries between 1990 and 2050, Berardi (2017) highlights the rising energy consumption and over-exploitation of natural resources, specifically in the building sector.

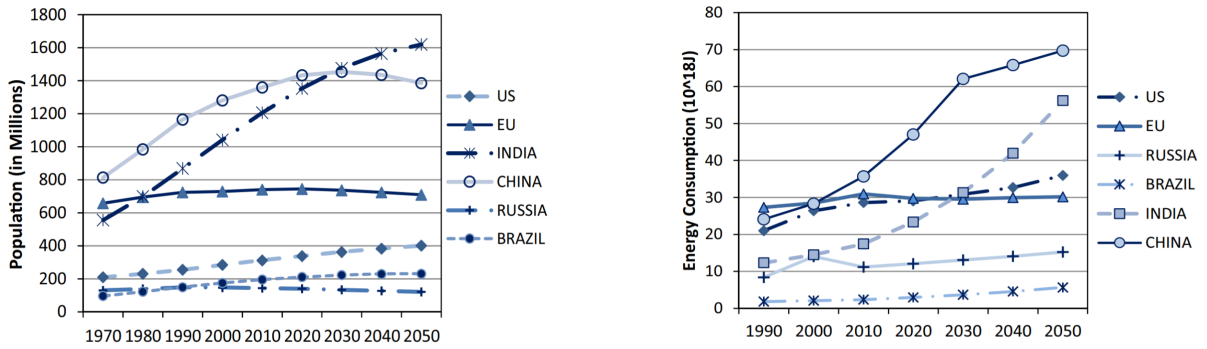

Figure 2.1 Population and building energy consumption levels in different countries from 1970 and 2050 (Berardi 2017)

Figure 2.1 demonstrates as time progresses, population and energy consumption seem to increase in several countries, even though the ascending rates are not similar in all countries, it is clear that population and energy consumption are directly proportional to one another and are simultaneously rising, causing major environmental impacts.

Worldwide awareness towards environmental impacts of resource depletion, energy shortage, climate change, and greenhouse gas emissions sparked concern about energy consumption trends placing tremendous pressure on the construction industry. As a result, the term sustainable construction has become more familiar in the global construction market. Sustainable construction aims to achieve safe and secure buildings with minimum impact on society, environment, and economy. In other words, satisfying the needs of the current generation without jeopardizing the needs of future generations, while focusing on ecological and socio-economic building systems (Karunasena et al. 2016).

As part of the sustainable initiative, Green Building Technology (GBT) has been perceived by many governments as a pioneer strategy in sustainable development, capable of reducing the negative environmental impacts of the AEC industry. Green Buildings is a resource-efficient building practice that acknowledges the value of natural resources, as well as improve the quality of life (Darko and Chan 2018). Research by Darko and Chan (2016), followed the Green Building research trend, showing the attention that Green Building development has witnessed over the previous years, and highlighting the rising number of Green Building research papers and contributions being made worldwide,

highlighting the significant impact on sustainable growth. The research examined many Green Building research interests such as project delivery method, certification, energy performance, and technological development, however, concluded by stating that even though Green Building development has been the centre for many types of research and academic publication, yet it is not considered as a primary concern when it comes to practical implications. Sustainability is still being overlooked as a primary attribute in the construction practice, nonetheless, the more academic pursuit will lead to further knowledge and awareness, eventually leading to the higher implementation of Green Building technologies and sustainable growth.

2.3 Building Information Modelling in the Construction Industry

2.3.1 Innovation in the Construction Industry

Innovation has been a key factor in the success of many industries. However, for many years, the construction industry has rarely contributed to innovation. When compared with other industries such as the pharmaceutical or automotive industry, the construction sector does not seem to strive in the technology department (Kamal et al. 2016). Despite the fact that innovation has shown an increase in productivity and gives a competitive advantage, the AEC industry showed little interest in investing for the development of the construction process. As a result, the AEC industry has been perceived as an underperforming industry that fails to deliver the optimum project value. Several pieces of research explore the reason behind such low -value performance, highlighting the lack of communication and coordination between directors, henceforth, a recurring issue (Selçuk Çıdık et al. 2017). Building Information Modelling has been an ongoing topic in construction research and is being perceived as a revolutionary tool cable of elevating the construction industry. However, many barriers still limit BIM's expansion and standardization in the AEC industry.

2.3.2 Introduction to Building Information Modelling

Information and Communication Technology (ICT) has a significant impact on the future of the construction industry, and with its successful implementation, may result in more effective and productive project outcomes. According to Bui et al. (2016), Building Information Modelling is one of the most beneficial ICT supporting the construction

industry today and yields advantages in collaboration, visualization, scheduling, design, and construction management. BIM implementation as an ICT application has taken-off in several of the developed countries such as the United States and the United Kingdom. Unfortunately, the same cannot be said in developing countries, mainly because there are still many limitations and barriers facing ICT adoption and BIM implementation in developing countries.

Building Information Modelling (BIM) is a process of generating and managing an integrated digital representation of diverse information throughout the project lifecycle on an interactive work platform (McPartland and Mordue 2018). Traditionally, the sharing of building information relayed on a paper-based communication approach, which offered a reliable delivery method. However, this method also caused fragmentation, in which information was misinterpreted or simply lost due to gaps in the delivery method. Research by Turk (2016) defined BIM in two manners, first as a model representing the physical characteristics of a facility through the sharing of information and data relations, throughout the lifecycle. Many argue that the process of creating information already exists and is demonstrated in the BIM maturity levels, shown in figure 2.2, however, BIM went beyond simple lines and structured a new way to represent objects.

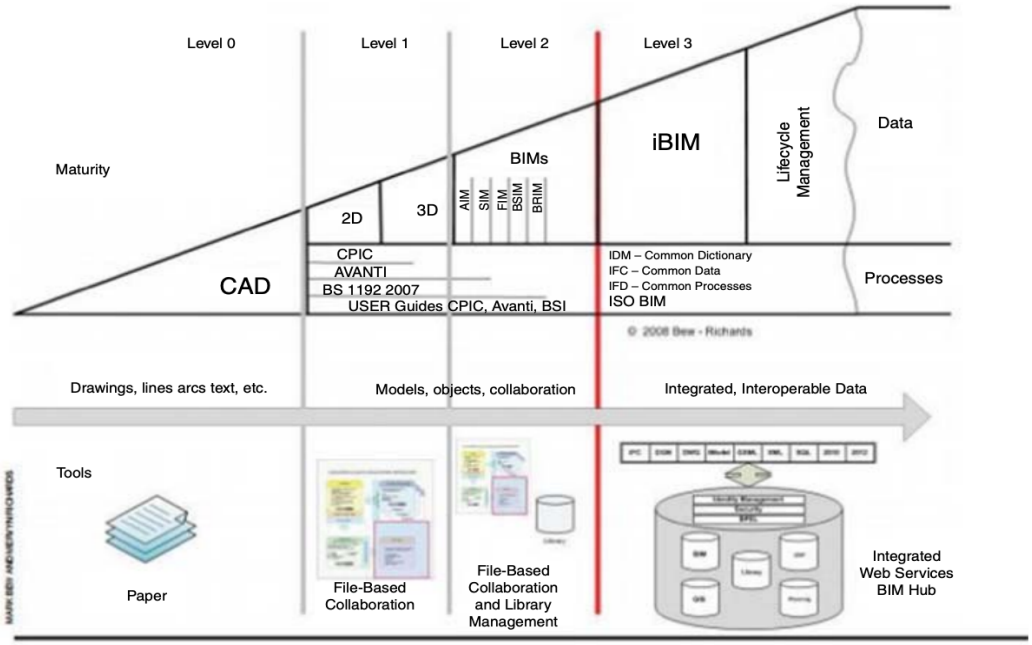

Figure 2.2 BIM maturity stages (Almuntaser et al. 2018)

According to McPartland et al. (2018), the BIM maturity levels demonstrate the milestones of moving the construction process from the drawing board to a digital age. As shown in figure two there are four levels for BIM:

- Level 0 BIM: a simple form of 2D drafting using paper, with no means of collaboration
- Level 1 BIM: this stage is a mixture of 3D CAD for conceptual work, along with 2D drafting with some electronic sharing of data
- Level 2 BIM: this is a collaborative working stage, in which all involved parties use their personal 3D CAD models, but that does not necessarily mean all parties are using the same model. However, they use a common file format allowing for easy data exchange thus facilitating the process of creating a BIM model. Most of the developed countries are currently working at this level.
- Level 3 BIM: the intended target of full collaboration between all disciplines under one single shared project model. Easily accessible and modifiable by all parties, therefore eliminating any threat of fragmentation.

The second definition refers to BIM as a combination of technological and organizational solutions capable of enhancing the managerial aspects of the AEC industry (Miettinen and Paavola 2014). Through visualization and collaboration, BIM can improve the design, construction, and facility management of a construction project, thus opening the door on a new possibility to enhance construction management (Succar 2009). McPartland et al. (2018) point out that there are three major aspects to consider when defining BIM. First, the structure of BIM which defines the way it is organized and the way it can be used to take real-world objects and place them a model form to prompt visualization. Second, the function of BIM as a method to manage commination and the sharing of information in one platform easily accessible by all members of the project. Finally, the behaviour of BIM, that of a social-technical system showing how different independent elements can be grouped together to achieve a single goal. Unfortunately, the research further states that many key features remain missing from BIM and will require a deeper investigation (Turk 2016). After exploring the vast and various definitions of Building Information Modelling, the common area between all researches identify BIM as an innovative tool in

the AEC industry that promises to facilitate the construction process by eliminating fragmentation, as well as, provide a platform for communication and information sharing. As the topic gathers more attention, research unlocks new potential for BIM. However, many factors and limitations challenge BIM's growth and the potential to expand knowledge on the subject.

2.3.3 Barriers and Limitations for implementing Building Information Modelling

Technological advancements continue to create change in the AEC industry, and with the aim to digitalize the industry, Building Information Modelling has been regarded as an innovative change capable of reinventing construction design and practice. Despite the major technological advancements in BIM, it is still considered risky and challenging to implement such technology knowing that its benefits have not yet been fully capitalized (Ghaffarianhoseini et al. 2017). There are many unresolved and unanswered questions regarding BIM, which creates barriers and limitations for its successful implementation. Building Information Modelling (BIM), a new and innovative technology, has opened the possibility for achieving better sustainable designs. However, as stated by de Paula et al. (2017), sustainability development in building design and construction tends towards the idea of technical solutions, considering the evolution of technological innovations in sustainability-related issues. However, it is important to keep in mind that these technical solutions are tools and are as good as the individuals managing them. Incorporating BIM in construction management presents its own challenges, even though BIM has aided sustainable growth during the design stage by facilitating visualization and communication, yet when it comes down to managerial aspects BIM has not yet proven its proper value. As a result, de Paula et al. (2017) inspects the managerial processes of design and construction in sustainability development, by identifying the factors that impact the environmental objectives of a project and the parties responsible. Unfortunately, the research does not explore the use of technological innovations in the managerial process nor the effect it could have on sustainable development. Research by Azeem et al. (2017), examines the barriers preventing the adoption of sustainable construction in a developing country. The findings show several barriers and highlight the lack of management, technology, social awareness, and financial resources as major issues. However, the research does not recommend any solutions on how to tackle these

barriers. Darko and Chan (2018) researched strategies for implementing Sustainable Technologies capable of reducing the barriers preventing sustainable development in developing countries. According to Rogers et al. (2015), BIM is perceived as a complex and expensive technology difficult to introduce into new projects. There are many aspects that need to be considered prior to BIM adoption, the first being financial consideration. Knowing that any new software requires a massive upgrade in hardware to run smoothly, BIM implementation has an overwhelming financial impact, since evolving from BIM level 0 which is based on lines and paper as represented in the BIM maturity stages, to BIM level 3 an integrated web service requires a major financial investment. On the other hand, all project participants are now using the same software, thus improving interoperability and eliminating fragmentation. Finance is not the only major issue limiting BIM's implementation. BIM adoption will result in many alterations such as (Rogers et al. 2015):

- Process change: traditional building methods will no longer apply, instead the entire design process will be brought and executed earlier in the project lifecycle. Even though this facilitates the design process and reduces clashes, it requires a highly skilled contracting team with knowledge of BIM to carry the design requirements, since now both the design and construction team are working on the same platform.
- Human resources: BIM adoption will require a different skill set. The changes resulting from BIM implementation in the AEC industry will lead to different tasks and activities, thus a different set of skills from the human resource pool. With low awareness of BIM, knowledge and training remain a barrier to the successful implementation of BIM.
- Legal factor: there is still little available knowledge on how BIM could influence the legal aspects of modern construction. Knowing that BIM will change the construction process form the pre-design stage to the operation and maintenance stage, implies that there will be a different set of rules and regulations throughout the construction process. With BIM capabilities not fully clear, this will result in gaps or confusing conflict resolution.

- Managerial factor: similarly, to human resources, BIM management will require a different set of skills and knowledge thus changing the role of the project manager. Hence different training and experience are now required to properly manage BIM throughout the construction project.

The AEC industry requires different teams to communicate with each other, therefore, to improve collaboration it is necessary to define BIM standards that facilitate information exchange between the project members. Unfortunately, the lack of BIM standardization makes it difficult to exchange data and update information (Barbosa et al. 2016). BIM standardization requires three main goals:

- Information exchange through standardized format
- Standardized understanding of the content from the information exchange
- Specification of the time the information should be exchanged

These BIM standards have not yet been properly established thus limiting the successful implementation of BIM, even though they present the opportunity to create a reliable method of information exchange capable of improving coordination, maximize productivity, ensure high-quality project delivery, and efficient information sharing and communication.

Many solutions for solving BIM implementation problems have focused either on technical issues such as software interoperability, software cost, and employee training, or on non-technical solutions such as legal issues, cultural change, and project delivery methods. However, according to Antwi-Afari et al. (2018), deeper knowledge of the critical success factors (CSFs) of BIM must be examined for improving its implementation. Critical success factors are key areas that must be properly achieved in order to produce the best performance (Rockart 1982). In the research, Antwi-Afari et al. (2018) examined several critical success factors and the key finding were based on:

- Collaboration between different entities of the project whether design, engineering, or construction
- Accurate 3D visualization of proposed project design
- Coordination and planning of tasks, activities, and construction work

- Creating a platform to facilitate data exchange, information sharing, and knowledge management
- Improve general works such as site layout and safety measures

Further research should be carried out on every aspect of the Critical Success Factors as suggested in the concluding statement. However, the CSFs are considered milestones for the advancement of BIM in the AEC industry.

Obviously, the proper implementation of BIM in the AEC industry remains a challenge. Fortunately, with an increasing number of research and academic journals tackling the barriers limiting the successful implementation of BIM, the possibility of achieving the full potential of BIM in construction projects no longer seems unreachable. Even though there are many factors challenging BIM implementation, the knowledge is available and plan to eliminate these problems is clear, yet this is a long process which requires time and effort to be properly executed.

2.4 Introducing Building Information Modelling into Sustainable Development

2.4.1 Definition of Sustainable Development and Sustainability Pillars

The world faces the challenge of balancing its future urbanization with its natural resources' conservation and environmental protection. Known for its contribution to economic growth, the AEC industry also has largely influenced the environment and society (Gan et al. 2015). The continuous unmanaged consumption of the world's natural resources, along with the uncontrolled population growth and over urbanization have led to severe environmental consequences such as climate change and global warming. As a result, sustainable development has become a more relative topic.

Sustainable development in the AEC industry is a relatively new concept that resulted from the dramatic environmental changes that have been requiring in the past years. By definition, sustainable development is "the development that meets the needs of present generations without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). In other words, sustainable development is based on preserving natural resources in order to meet

current and future energy demands. Unfortunately, over-exploitation of current resources today has led to dramatic environmental changes, hence creating several problems and issues that jeopardize the health and well-being of current and future generations. According to Yin et al. (2018), even though the concept of sustainable development has been relatively present for some time, the demand for sustainable construction is still low, due to several barriers preventing its implementation such as:

- Difficulty complying with sustainable legislations
- Changing the organizational structure and process
- Lack of technology and innovation
- Lack of awareness, education, and training

Sustainability Development focuses on three major aspects economical sustainability, social sustainability, and environmental sustainability also known as the “sustainability pillars” (Karunasena et al. 2016).

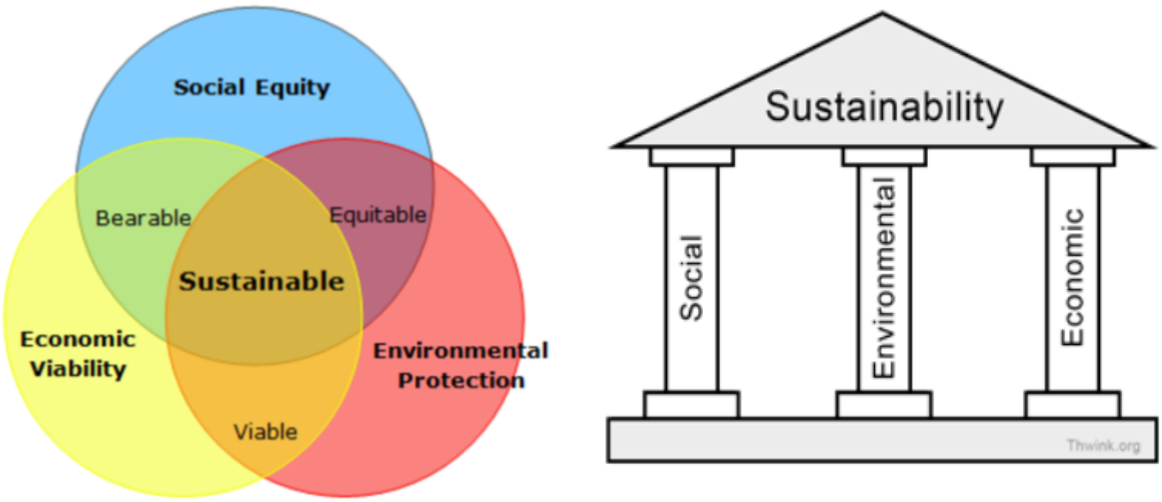

Figure 2.3 Sustainability Pillars (The Three Pillars of Sustainability 2018)

The sustainability pillars breakdown the concept of sustainable development into three major categories economic, social, and environmental sustainability, defining how each aspect plays a definitive roll in contributing to a better sustainable outcome by analyzing each aspect individually. According to Khan et al. (2016) and Chong et al. (2017), each

category presents its own challenges, but offers the opportunity for measuring sustainability:

- Social sustainability: it is based on people's ability to live in a fashion that best provides their needs without harming future generations. The outcomes are favourably achieved when considering client satisfaction. In the AEC industry, public health and safety are critical factors to improve social sustainability. Furthermore, improving communication between the workforce and the community result in safer and more productive management. Therefore, it is necessary to change the AEC industry, and the best way to achieve the right conditions is by recruiting and training talented individuals through which improvements can be made.
- Economic sustainability: it is more complicated to quantify economic sustainability since there have not been many data recorded demonstrating economic sustainable development (Gibbs and O'neill 2014). However, it is imperative to highlight the importance of saving from the life-cycle cost and construction time of any built facility, in order to invest in more innovative construction techniques and training programs. Key Performance Indicators (KPI's) aid in measuring performance and can help utilize new construction material, new building technology, new contract forms, and integrated communication.
- Environmental sustainability: the process of reducing greenhouse emissions, minimizing waste generation, air pollution, noise pollution, and water consumption to improve the quality of life for the current generation and guarantee a future one. Using Environmental Performance Index (EPI) and lean construction, the AEC industry can mitigate and lower the negative impact on the environment, thus achieving better sustainable outcomes, more energy conservation, and an overall healthier living environment.

The sustainability pillars provide a relative insight on sustainable development, however implementing Building Information Modelling can aid each of these aspects throughout the project lifecycle. However, the use of BIM in sustainable development has not been

developed to full potential and therefore could not be integrated properly in any of the sustainability pillars.

2.4.2 Building Information Modelling in Sustainable Development

Building Information Modelling is regarded as a revolutionary technology to facilitate the management and integration of information throughout the project lifecycle. With growing concern over sustainable development and the rising growth of BIM, merging the concept and technology together could improve the sustainable performance of the AEC industry. To understand the influence of BIM in sustainable growth, there is a need to establish a relation between the two concepts, therefore Lu et al. (2017) examined previous journals and different types of BIM applications to propose the “Green BIM triangle”. In the research, green buildings were recognized as a leading method to improve sustainable development in the AEC industry. Green buildings could improve energy performance, lighting analysis, and construction waste generation, therefore the nexus between green buildings and BIM presents a great opportunity for developing sustainable construction.

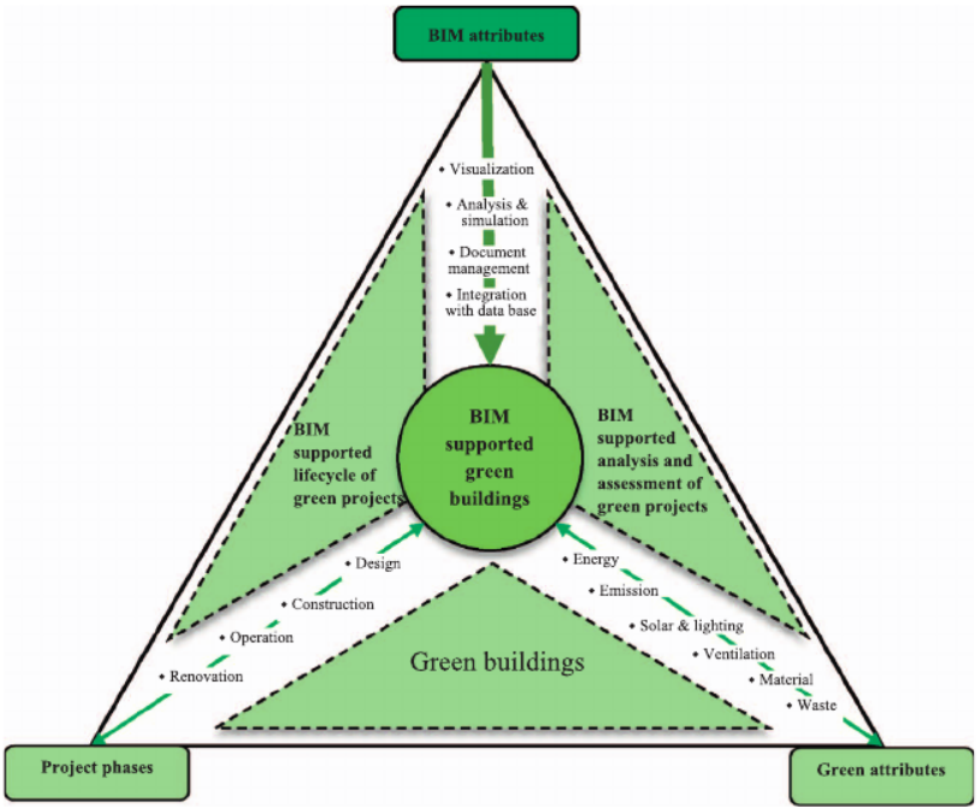

Figure 2.4 Green Building Triangle Taxonomy (Lu et al. 2017)

As shown in figure 2.4, there are two major criteria linked with green BIM, first Building Information Modelling which falls under “BIM attributes” that assist in visualization, analysis, simulation, document management, and integration with various databases. Second is green buildings, which fall under “green attributes” that consider the elements of study to achieve better Green Building development, both in correlation with the “project phases”. Green attributes focus on the elements that could be improved using BIM software such as energy, thermal comfort, carbon emissions, water, material waste, daylighting, natural ventilation, and acoustic analysis, while project phases address the dimensions presented throughout the project life-cycle such as design, construction, operation, maintenance, and demolition.

Figure 2.5 Project lifecycle (Carey 2018)

As seen in figure 2.5, the different stages of a project lifecycle in which BIM can support different sustainability issues. According to Chong et al. (2017) and Lu et al. (2017), BIM can aid building performance in every stage of the lifecycle, such as:

- Planning stage: Careful planning will remove all unnecessary repetition of work, therefore, BIM implementation during the conceptual design phase will improve social sustainability by providing a safe and healthy work environment, and improve the owner-designer-contractor relationship, as well as minimize variation costs while eliminating the threat of future unforeseen errors. The traditional building delivery methods leave little room for BIM to play an influential role, therefore it is necessary to consider a new Integrated Project Delivery method (IPD) (Fadeyi 2017).
- Design stage: Currently known as the most controlling stage for BIM. The majority of BIM tools operate at this level by facilitating data exchange between all project

participants, thus aiding in producing a visualized building performance analysis and simulation, while providing different design alternative and material specification. At this stage, BIM integration has the most beneficial social, economic, and environmental sustainability outcomes, for example, improve interoperability, facilitating cost estimations, and generating energy simulations.

- Construction stage: Known for its most significant environmental impacts, at this level BIM-supported construction can facilitate project information interchange thus providing designers and contractors the opportunity to work together on generating 4D and 5D simulations for project forecasting, interface management, and logistic planning. BIM can aid in the selection of material and suppliers, produce less material waste, reduce air and noise pollution, provide flexibility in design changes, generate cost reports, and create an as-built site layout for tracking on-site delivery. The knowledge of BIM-supported construction is still limited, mainly because BIM is still being regarded as a design tool and is still rarely recognized as a tool aiding in the construction process.
- Operation and maintenance: BIM goes beyond just design and construction. Monitoring energy performance has great benefits for environmental sustainability. Lack of awareness on the BIM potential to be used outside design has diminished the possibility of implementing BIM in the AEC industry and benefit from the BIM tools that further push sustainable development.
- End of Project Lifecycle: the emphasises is on delivering customer satisfaction and to make sure every aspect of the project has been documented for future reference, which can be easily done through BIM.

2.5 Building Information Modelling Framework and Theory:

The need to implement Building Information Modelling in the AEC industry is gaining attention progressively. However, according to Succar (2009), several constructs derived from organizational studies, information systems, and regulatory fields highlight the lack of a BIM research framework to organize the knowledge for successfully implementing BIM. Thus Succar (2009), developed a framework to investigate the BIM domain, promote understating their subdivisions, create an integration between products and process modelling, and finally, link academic and industrial understanding of BIM. The research

introduces a BIM framework that layouts the BIM fields of activities, stages, and lenses, as can be seen in figure 2.6.

Figure 2.6 BIM implementation framework (Succar 2009)

The proposed framework generates knowledge modules, templates, and tools that can assist in the implementation and teaching of BIM thus benefiting both the industry and academia. As well as, the framework application spreads over the whole lifecycle phases

thus its implementation impacts organizations at project and industry levels. These deliverables will improve BIM maturity thus impacting the project lifecycle, to deliver an Integrated Project Delivery (IPD). Succar (2009) developed a delivery framework, specialized ontology, and visual language to investigate the BIM domain, however, the research is considered “scene setting” and many non-foundation framework parts were excluded and thus requires more in-depth investigations with different methodological approaches.

A similar framework presented by Khosrowshahi and Arayici (2012), developed a map for the successful implementation of BIM in the UK construction industry as shown in figure 2.7.

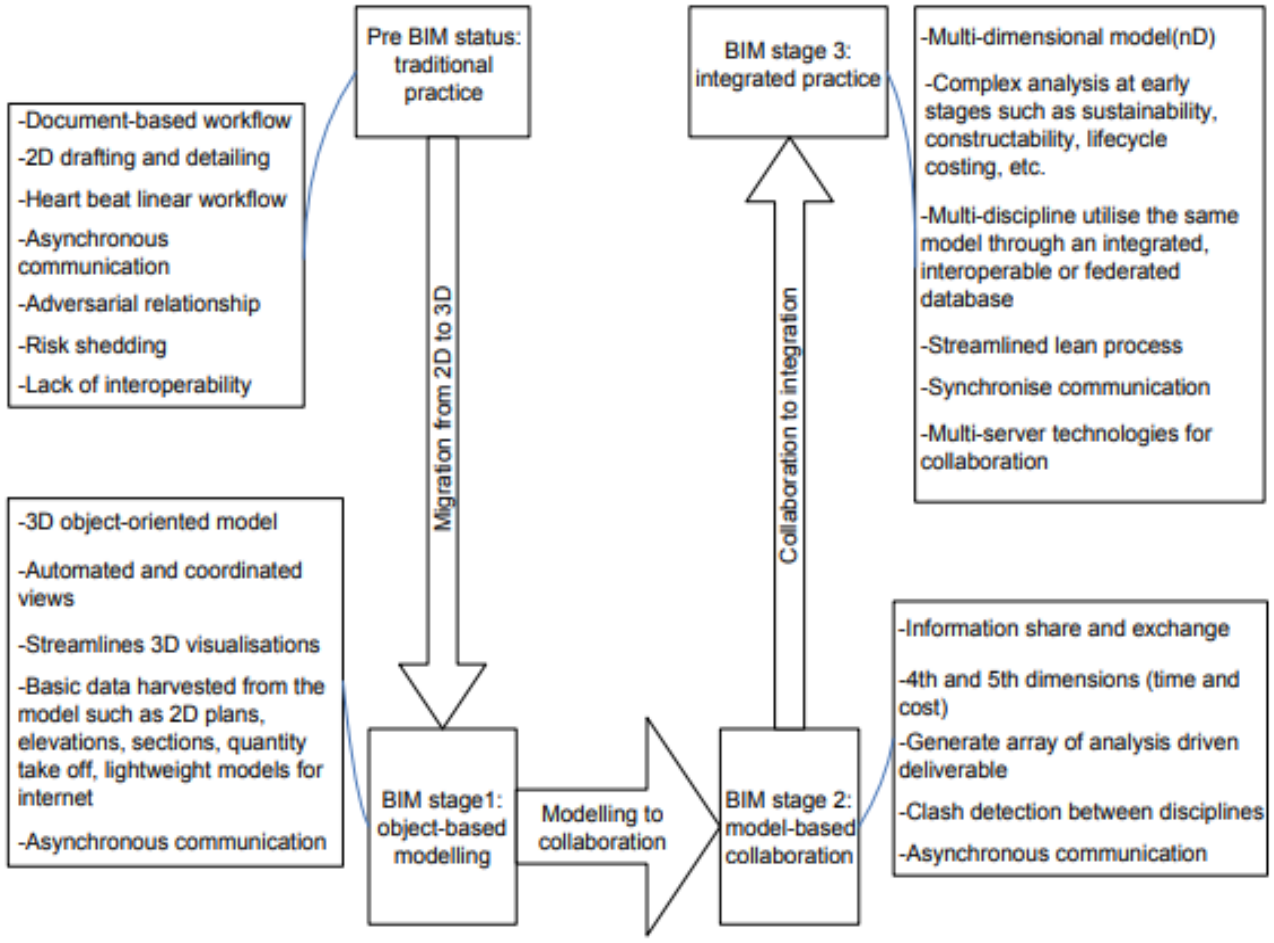

Figure 2.7 BIM implementation stages in BIM maturity levels (Khosrowshahi and Arayici 2012)

The research aimed to develop a framework to initiate the adoption of BIM and replace the traditional CAD method. According to Khosrowshahi and Arayici (2012), extensive research covered BIM as a revolutionary technology yet very little research examined BIM as a business model that entails its use. After introducing a systematic literature review and applying the concept of mapping to analyse, the research identified the BIM maturity stages and subdivided into a more systematic classification to further understand the BIM fields, similar to the research carried out by Succar (2009). The research highlighted that BIM use at stage 3 of the maturity level remains low, even though people are highly aware of its existence. Unfortunately, level 3 BIM presents several challenges such as overcoming the resistance to change, raising the potential of BIM, training and education, developing an effective implementation strategy, setting guidelines and standards. Even though the proposed map or framework facilitated the process of BIM implementation, yet many factors were not considered, such as the analysis did not involve inferential analysis or test of significance due to the descriptive nature of the research. Future research recommendations highlighted the intricate BIM issues that have enabled certain countries to embrace BIM while others prevented it.

As a result, the proposed framework carried out in this research will be applicable to the Lebanese AEC industry, where BIM capability has not yet achieved its full potential. Similar to the above-mentioned frameworks, many barriers and limitations still hold the adoption of BIM in the AEC industry, yet identifying these limitations will be the first step for uncovering the proper implementation strategy of BIM. The proposed framework will consider the BIM maturity levels as well as the project lifecycle. In addition, the framework will consider the social, economic, and environmental impact of implementing BIM in the Lebanese AEC industry and set the foundation for the proper execution strategy.

2.6 Chapter Summary

This chapter has introduced the importance of innovation in the construction sector, and as a result, Building Information Modelling has been recognized as a revolutionary tool that can elevate the performance of the construction industry. BIM is a repository of building information easily accessible by all project participants. The chapter highlighted the benefits of BIM as well as the barriers and limitations that have prevented its

successful implementation which inspired much different research to examine critical success factors and develop frameworks for BIM's proper implementation strategy. The chapter also defined sustainable development and the critical role it plays in the economy of any country. However, lack of awareness and regulation have led to significant environmental impacts, that BIM may carry the key to resolve. BIM and sustainable development have been growing concerns in the AEC industry and with many challenges facing their development, a framework is needed to identify the proper strategy to successfully implement BIM in the AEC industry.

Chapter III: Current Sustainable Performance in Lebanon's Architecture, Engineering, and Construction Industry

3.1 Chapter Overview

The following chapter will introduce Lebanon's current sustainable performance. By looking into Lebanon's geographical environment and historical records, interpret Lebanon's need to improve sustainable construction. Reviewing previous research will highlight the current situation of sustainable development in the Lebanese AEC industry. Moreover, take a closer look at the understanding of Building Information Modelling and its role in the Lebanese construction sector.

3.2 Sustainable Growth in Lebanon

3.2.1 Lebanon Geography and Environment

Lebanon, a small mountainous country with a total area of 10,425 km^2, is located in the Mediterranean region, as shown in figure 3.1, with a population of about 7 million people, and is considered a blooming area for many diverse natural species (Myers 2000). Beirut, the capital of Lebanon, sits at the Mediterranean Sea and is currently the highest populated area with approximately 2 million residents (World Bank 2018). Unfortunately, Lebanon's over urbanization along with the surge in its population due to neighbouring refugees have resulted in unprecedented deterioration of its natural habitat. According to Faour (2015), the reconstruction period after the Lebanese civil war has led to massive unplanned urbanization polluting surrounding countryside, mountains, rivers, and coastlands. In addition, Lebanon witnessed an unexpected increase in population by 30% from Syrian refugees since 2012 (Ammar et al. 2016). Therefore, according to Kareiva et al. (2007), a sudden increase in population over a short period of time usually result in a negative impact on the environment and losses in biodiversity.

Figure 3.1 Lebanon Geography and Location (Lebanon Map and Satellite Image 2018)

According to Bou Dagher-Kharrat et al. (2018), Lebanon has witnessed anthropogenic disturbances in its biodiversity and is dire need to preserve its ecosystem, suggesting a framework to preserve the ecological environment, as well as stating the critical the situation currently is in Lebanon. Therefore, Lebanon is in desperate need to consider a different approach for its urbanization strategy, hence the need to consider sustainable construction and development.

3.2.2 Lebanon's perspective on Sustainable Development

As a developing country with a history of war and vast structural damages, Lebanon is witnessing a noticeable economic growth compared to previous years and therefore is expected to take on several new construction projects in the nearing future. According to the Lebanese Order of Engineers, the rising number of construction permits being issued shows a relatively wide potential to expand the construction industry in Lebanon (EIU ViewsWire 2016). Unfortunately, due to its poor economic statues, the Lebanese construction industry faces several major issues, such as delays in construction projects and cost overruns, which overshadow the importance of sustainable development. Sustainable development has not been considered as a priority, and with the continuous

consumption of natural resource to supply energy, negative environmental impacts were inevitable. Therefore, in the hope of attempting to control these negative impacts, Green Building development should be investigated as a mitigation to support sustainable development.

The construction industry, known for generating high levels of pollution, has the potential to reduce the negative environmental impacts and overconsumption of raw material. Although the Middle East region lacks natural resources and struggles from unresolved political and social issues, it is attempting to redirect construction to a more sustainable manner. The Middle East witnessed a growing population and an improving tourism sector over the past years, hence, the increasing demand for construction and building projects. Issa and Al Abbar (2015) examined the opportunities and challenges for introducing Green Building codes in several countries in the Middle East, such as Qatar, UAE, and Lebanon, as part of sustainable development. The Middle East region is faced with many challenging circumstances, such as:

- natural problems due to high temperatures, dry climate, and low availability of freshwater
- lack of awareness of sustainable development, even though there is a high level of education in the region, however, the focus primarily remains on improving the economic situation
- overconsumption of natural resources and raw material
- retrofitting of existing buildings to be more energy efficient is considered as a lucrative process, and due to the current economic situation, is not considered as a feasible option

In Lebanon, the Lebanese Green Building Council (LGBC) a non-profit non-governmental organization adopted the ARZ building rating system and focused on energy efficiency and water conservation. Unfortunately, due to the country's minimal sustainability awareness and political instability, the rating system was not considered mandatory and was only included in a few projects. Lebanon's economic growth and population increase resulted in the rising demand for building construction and infrastructure. However, with the country's low level of awareness in sustainable development, Lebanon experienced

a significant increase in the level of pollution and carbon emissions, placing the Lebanese community under tremendous risk. The table below represents the rising economic growth, increasing population, and escalating levels of carbon emissions with respect to time.

Table 3.1 Rising economy, population, and carbon emission with time (World Development Indicators | Databank 2018)

Time Data	1990	1995	2000	2008	2012	2016	2018
GDP (billion $)	2.838	11.719	17.26	29.228	44.231	51.239	56.639
GDP Growth (%)	26.5	6.4	1.3	9.2	2.1	1.6	0.2
Population (million)	2.80	3.52	3.84	4.76	5.53	6.71	6.84
Population Growth (%)	2.8	3.6	2.5	-0.1	6.3	2.7	0.5
Energy use (kg oil/capita)	697.1	1249.7	1277	1139.8	1294.7	-	-
CO_2 emissions (ton/capita)	2.9	3.8	4.0	3.6	4.1	-	-

As shown in Table 3.1, Lebanon witnessed significant economic and population growth over the past 30 years. Hence, the demand for fossil fuels to supply energy rises, and since Lebanon has not yet considered prioritizing sustainable development in the construction industry, carbon emissions continue to escalate as energy consumption remain unsupervised. As a result, Lebanon is in desperate need to re-examine its sustainable strategies otherwise, living conditions will be more difficult than they already are.

Research by Mezher (1997), explores the environmental problems threatening Lebanon's well-being. The research identifies several contributing factors for environmental deterioration such as:

- Lack of solid waste management, where waste being generated from the construction or demolishing of buildings are being left untreated in open land
- Water and air pollution, due to electrical plants and cement factories releasing chemicals in nearby streams or into the atmosphere
- Lack of managerial, professional, and technical skills
- Shortage of capital
- Damaged infrastructure
- Primitive technology as well as an absence of research, development, and innovation
- Government corruption, social and political instability

Supporting this claim, research by El Asmar and Taki (2014) states that Lebanon's economy is emerging from a crisis and there are remarkable developments in commercial, residential, and industrial properties. Unfortunately, through simple observation, realizing that these developments remain inadequate to sustainable standards is very clear. Houses remain to be built with no regards to sustainable regulations, eventually leading to a more chaotic natural landscape, air, water, and noise pollution. The lack of interest in national land-use planning, coordination of environmental management, and updating environmental regulations resulted in urban aesthetic pollution and chaos. A case study examined the city of Zouk Mosbeh, a heavily populated coastal area in Lebanon. The findings show a high level of air, water, acoustic, solid waste, soil, and aesthetic pollution. As a result, there must be a change of attitude towards sustainable development, and the government should consider its integration in social, economic, and environmental strategies. A "bottom-up" approach was recommended, which supports collaboration and cooperation between directors and the public giving equal opportunities in the participation of policy formulation and implementation, however, authority remains in the government's hands (El Asmar et al. 2012).

In developing countries such as Lebanon, social and environmental sustainability are only taken into consideration as long as their economic benefits for the directors. It is important to deduce the intersection between business and sustainability.

3.3 Current use of Building Information Modelling

To this point, Building Information Modelling has been recognized by many developed countries as a tool capable of elevating the construction industry, and many of these developed countries have taken initiative to adopt BIM in the project lifecycle. Whether design, construction, or operation and maintenance BIM has been perceived as a game changer. Even though many barriers still limit its successful implementation, developed countries are aware and deriving solution to eliminate these barriers such as the UK as shown in figure 3.2 and other developed countries as shown in figure 3.3.

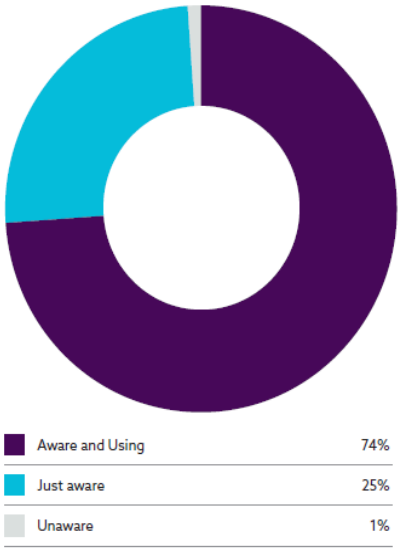

Figure 3.2 BIM awareness and usage in the UK (The National BIM Report 2018)

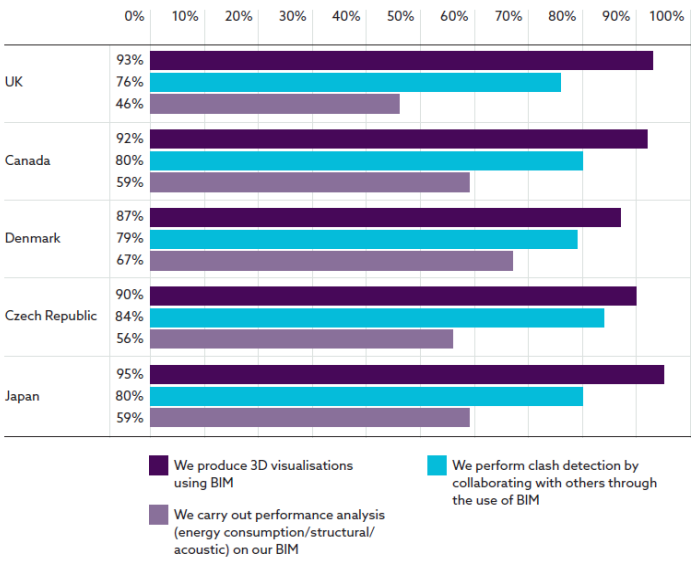

Figure 3.3 BIM awareness and usage in different countries (McPartland 2018)

Unfortunately, in developing countries, such as Lebanon, limited research has been conducted to understand the role of BIM in the AEC industry. The Middle East region has shown the lowest BIM adoption rate compared to other developed countries, as a matter of fact the Middle East have not taken any steps to support BIM in the public sector and only 25% of firm operating in that region have shown BIM adoption for basic tasks such as 3D visualization and drawing extractions (McGraw-Hill 2011). According to Bui et al. (2016), almost no research on BIM exists in developing countries prior to 2013.

The weak BIM adoption in developing countries and the Middle East region proves the low levels of awareness towards the importance of construction innovation, and the lack of prioritizing sustainable development as seen in figure 3.4 (Haron et al 2017).

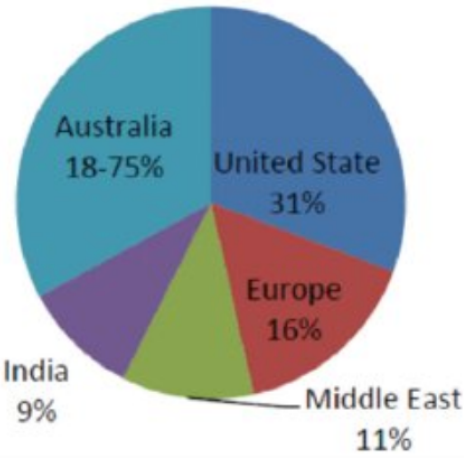

Figure 3.4 BIM adoption rate in construction industry (Haron et al. 2017)

In addition, Lebanon's poor economy did not support its position to develop its AEC industry. Undoubtedly, this led to its unorganized urbanization and negative environmental impact. The best approach to understand BIM is Lebanon is to compare with other developing countries which also suffer from lack of awareness on BIM. Clearly this lack of knowledge and negligence such set developing countries, Lebanon among them, on a path of environmental consequences affecting the safety and well-being of its society, hence the desperate need to create and adopt new technology capable of redirecting their path for a better sustainable outcome.

With the increasing rate of urbanization in Lebanon, sustainable development should be a primary concern, especially to the construction sector, knowing that it is the largest contributing industry for waste generation and rising pollutant factors. However, due to low government involvement to standardize and regulate sustainable development, the construction found little concern with the issue and carried on delivering the project with low quality and no future direction. The focused remained on project delivery being on time and budget, disregarding the impact on future generations. The low awareness levels on the importance of sustainable development, and its application in construction, have led to the severe degrading of the Lebanese construction industry, and its identification as a poor substandard industry, specifically when compared with neighboring countries which have accomplished far more in much less time. Understanding how sustainable development has reached such low measures in

Lebanon requires a closer look at the current state of research and awareness on the subject of sustainable development.

When asked about the performance of sustainable construction in Lebanon, interviewees who took part in this researched highlighted its lack of priority and emphasized its low demand in the construction market. Due to the low awareness levels on sustainable development in Lebanon, clients are not interested in contributing to a more sustainable project. As well as, there is little research and knowledge on the whole subject, and more specifically, there is limited experience when working with sustainable construction making it harder to achieve. Nevertheless, the importance of sustainable construction is developing and become a more researched and examined topic in the Lebanese industry.

Recent research focused on adopting new technological products aiming to improve sustainable constriction and lower waste generation. El Katat et al. (2018) examined Lebanon's sustainable classification with respect to other Middle Eastern countries. The research examined income indicators to address the improvement of social sustainability. One of the main barriers of BIM implementation in the Lebanese construction industry identified in the interviews was low income for the employees. This research found that people who are familiar with BIM and have working knowledge of it, preferred to work outside of Lebanon due to low incomes offered in the Lebanese market. The low-income factor has led BIM experienced employees to leave the country and produce in outside industry, and as result, this is one of the main social barriers that have held the development of BIM. With limited experience and knowledge, the labor supply chain in Lebanon has become weaker and therefore unable to improve sustainable development. El Katat et al. (2018) used data mining in Lebanon and the Middle East to show the strength of participation of population in development. The results show that Lebanon is unlike any other country in the region, majority of the income is being transferred in from outside the country. Which implies that the standard of living situation in Lebanon is due to the worker outside the Lebanese market. In terms of sustainable development, all working labor that can improve sustainable performance in Lebanon, are using their skills and strength in outside market, thus leaving the Lebanese industry stagnant. The social factors that have led to the low levels of sustainable development in the Lebanese

construction industry are similar to the social barriers that have held the implementation BIM. The relation between BIM implementation and sustainable development in the Lebanese construction industry, is based on similar factors. Therefore, in order to improve sustainable development in construction sector, BIM is the tool that can provide the option for further improvements. Hamzeh et al. (2016) investigated the implementation of new techniques, philosophies, and technologies in the Lebanese construction sector, such as lean construction and Last Planner System (LPS), in an attempt to improve sustainable performance. The research examined a case study for a project were the use of these innovative methods showed improvements in the construction process such as visualization, collaboration, communication, and director involvement. More benefits were expected, yet the limitation, such as reluctance of the employees to shift to the new system, did not aid in achieving the expected outcome. Nevertheless, these adopted methods showed noticeable improvement in the project performance. It could be considered as a step by step process of initiating progress in sustainable construction. However, BIM has been recognized as the leading technological innovation in the construction industry and was not considered in Hamzeh et al. (2016) research. Implementing such technology could push sustainable development further, as even more research attempted to include more technological advancements in the Lebanese construction sector. AlZaghrini et al. (2019) attempted to use GIS technology to optimize and manage construction and demolition waste in Lebanon. The research focused on the importance of improving environmental condition in Lebanon by eliminating economic, environmental, and legal barriers in order to reduce generated waste and aim to achieve a more sustainable environment. The research developed a framework using criteria of GIS models and factors that impact environmental sustainability in Lebanon. The outcome of the research demonstrates that the use of such technological advancements can lead to improved design standards and legislation for the development of environmental sustainability. Based on the in outcome resulting from the interviews carried out in this research, environmental sustainability is being overlooked with no standardization or legal action that can decrease negative environmental consequence on improve environmental sustainability.

The factors that influence sustainable development in the Lebanese construction sector are similar to the barriers that limit BIM implementation in the industry. Economic, social, and environmental sustainability could be improved in the Lebanese sector if the economic, social, and environmental barriers limiting BIM implementation could be overcome. Similar limitation holds BIM implementation and sustainable development in the Lebanese construction industry.

Table 3.2 Factors influencing Technological use (AlZaghrini et al. 2019)

Thematic group	Factor	Criteria
Socio-Economic	Urban areas	Areas with densities exceeding 2000 capita per km^2 are excluded from the analysis
	Land cover	A minimum buffer distance of 1000 m is recommended for agricultural lands and forests
Infrastructure	Roads	A minimum buffer distance of 600 m from main roads is recommended
Hydrology	Water bodies	A minimum buffer distance of 500 m from water bodies and reservoirs is recommended
	Precipitation rate	Areas with a rainfall rate exceeding 1,200 mm per year are excluded from the analysis
Topography	Slope	Areas with slopes exceeding 18 degrees are excluded from the analysis
	Snow Cover	Areas located above Lebanon's snowline (1300 m) are excluded from the analysis
Geology	Seismic Conditions	A minimum buffer distance of 500 m from any major or minor fault is recommended

Factor	Fuzzy membership function	Midpoint	Spread
Population density	Fuzzy small	200	5
Distance from agricultural lands and forests	Fuzzy large	1000	5
Distance from springs, rivers	Fuzzy large	500	5
Precipitation rate	Fuzzy small	600	5
Slope	Fuzzy small	9	5
Snow elevation	Fuzzy small	775	5
Faults	Fuzzy large	500	5

Chidiac El Hajj et al. (2017) found that education may be the key to increase awareness on the impotence of sustainable development in Lebanon. The research pointed out that

there is a lack of sustainable education in universities and institutions of higher learning and overlooking the value of sustainability has led to these consequences today. Similarly, as there is no education of sustainable development, there is no BIM curriculum in higher education institution. Education is the key for raising awareness and improving knowledge, and the fact that higher education institutions have overlooked the value of sustainable development, have led to the economic, social, and environmental consequences Lebanon battles today. As a result, to improve performance today and sustainability tomorrow, higher education institution should enroll BIM as part of their curriculum and focus on developing design methods that can be adopted for sustainable construction.

3.4 Chapter Summary

The Lebanese AEC industry plays a major role in the country's economic performance, however, with limited research investigating BIM implementation as well as sustainable development, the country has experienced a significant environmental consequence. This chapter highlighted the factors limiting BIM implementation in the Lebanese AEC industry, as well as, take an in-depth view of the perspective of sustainable development for construction industries. The low implementation rates of BIM have prevented the growth of the AEC industry and have negatively impacted society, economy, and the environment.

Chapter IV: Research Methodology

4.1 Chapter Overview

In chapters 2 and 3, a literature review was carried out with an aim to introduce new concepts and gather new information, while questioning the limited and theoretical context of adopting Building Information Modelling for sustainable development in developing countries. This lack of knowledge inspired involvement in the Lebanese AEC industry to thoroughly examine the barriers and limitation mentioned in the previous chapters and answer the questions that the literature could not. The following chapter outlines the research design and approach used to gather new information and analyse the data in forthcoming chapters. This chapter will discuss philosophical assumptions and strategies underpinning this study, as well as the research methodology affiliated in sampling procedures, data collection methods, and the data analysis process.

4.2 Research Paradigm

4.2.1 Understanding the Research Paradigm

A research paradigm is a system that will guide the decision-making process from the assumptions made in the research design to data collection and analysis methods (Myers 2013). According to Creswell (2003), research is based on establishing the proper philosophical assumptions that best supplement the validity of the research, as well as the research method that best strengthens the knowledge of the study. Robson (2002) states that the approach towards achieving the aim and objectives of the research, contribute to the pattern of information assumed or developed such as quantitative or qualitative research methodology. Robson (2002) based the quantitative research approach on numerical figures and statistics appropriate for the validations of theories, while the qualitative research approach on descriptive reports for further understanding and going too in-depth knowledge of a problem. Combining both approaches for a mixed-method methodology further strengthens the quality of the research, but it is important to keep in mind the importance of the assumptions and their effect before commencing any research (Yin 2003).

4.2.2 Research Philosophy and approach

The research philosophy is defined as the researcher's belief on how the data should be gathered, analysed, interpreted, and utilized, but the researcher's approach should differentiate two terms what is known to be true, known as epistemology, and what the researcher believes to be truly known as doxology (Lehaney and Vinten 1994). Therefore, the purpose of the research is to transform what the researcher believes to be true to a known truth. The research philosophy is critical for the success of the study; therefore, it is necessary to explore different types of research philosophies to understand the different characteristics and find the appropriate approach for the study carried out.

Saunders et al. (2007) categorises the research process into different layers, establishing the concept of the "Research Onion" shown in figure 4.1. The different layers represent various approach methods that can be carried out to create the research process, for example, the first layer (the outer layer) represents different research philosophies that can be adopted for the study, and so forth.

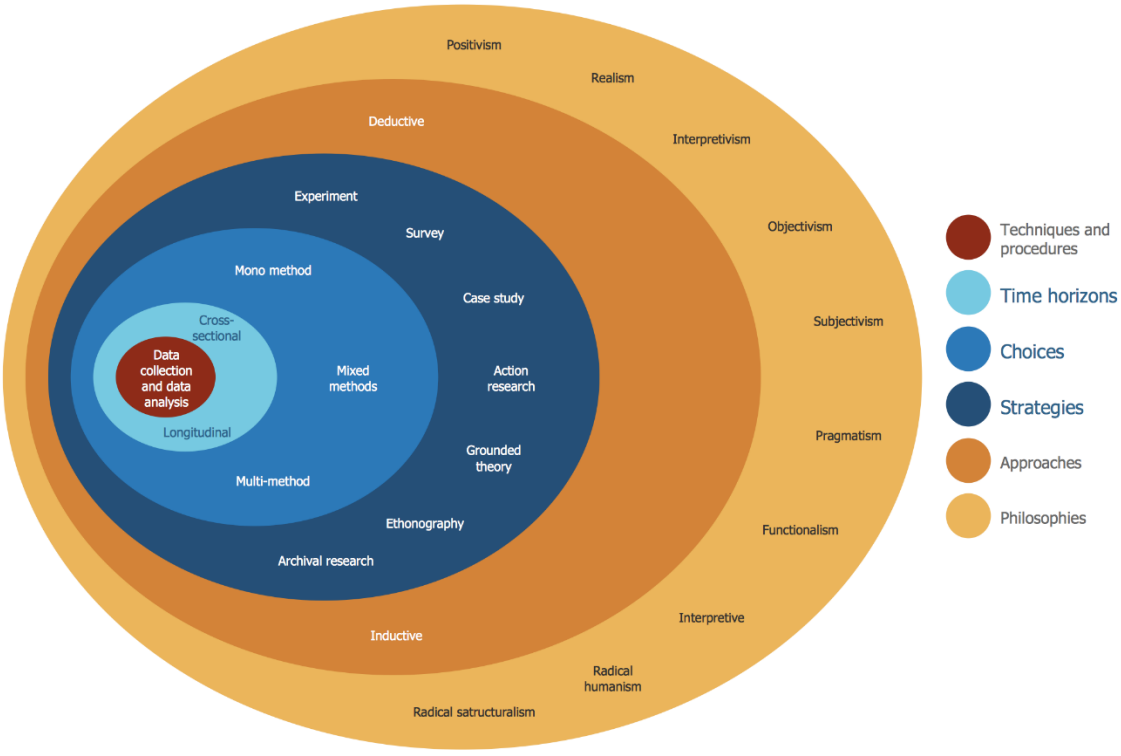

Figure 4.1 Research Onion (Saunders et al. 2007)

As shown in figure 4.1, the first step for successful research is selecting the appropriate philosophy. The philosophical choices of the research set the fundamental beliefs; therefore, it is important to understand and differentiate between them.

According to Saunders et al. (2009), the major philosophies are positivism, interpretivism, critical realism, postmodernism, and pragmatism.

- Positivism: is based on the assumption that reality is stable and can be observed with objectively and measurable properties. It best applies for scientific reasoning and generalization aiming to improve knowledge (Remenyi 1998). This method best fits when using a large sample and quantifying observation.
- Interpretivism: is based on the assumption that humans are different from physical phenomena and create their own reality. This approach studies different people from different background and environment clearing different realities, to achieve a new and deeper understanding. With a focus on enriching knowledge, the researcher must get involved in the study and understand the environment's point of view and value.
- Critical realism: focuses on reality as an external and independent phenomenon but cannot be accessed directly by human observation and knowledge. This approach claims human sensation diverse objectivity and shifts away from reality, therefore human experiences are considered empirical and irrelevant to reality (Reed 2005). It is challenging to get involved while neglecting the role of culture and belief in reality.
- Postmodernism: emphasis on the importance of language questioning the accepted way of thinking. It goes beyond interpretivism and critics positivism and highlights the importance of language. It believes that language produces order and recognizes it as partial and inadequate. Its purpose is to bring out what has been excluded from what people believe is the reality.
- Pragmatism: this philosophy supports action by considering theories, concepts, and ideas not in an abstract form but as a form of action with consequences. It starts with a problem and aims to create practical solutions by re-creating belief.

Following the philosophy, the research onion's second layer is the approach. According to Trauth (2001), the research approach should be selected relative to the research problem. Therefore, to properly select a research approach it is important to consider the following factors:

- Research problem
- Researcher's theoretical lens
- Level of uncertainty surrounding the phenomena
- Researching skills
- Researcher's control over the environment

As shown in figure 4.1, the research approach can be either deductive or inductive. Deductive reasoning occurs when the conclusion is derived logically from the available facts by working from general to more specific points. While inductive reasoning has a more degree of uncertainty since the conclusion is taken from a specific observation and then developed to a broader generalization or theory (Ketokivi and Mantere 2010).

4.3 Adopted Research Design Approach and Rationality of Choice

4.3.1 Qualitative research method, philosophy, and approach

4.3.1.1 Qualitative Method

After understanding some basic principles on the importance of selecting the appropriate research philosophy and approach, it is imperative to match the aim of this research with the best fitting research approach. The objectives of this research are to identify and understand Building Information Modelling implementation in the Lebanese AEC industry, as well as, explore BIM tools capable of enhancing sustainable development in construction projects. Based on the literature, Building Information Modelling still faces many barriers preventing successful implementation in developing countries (Bui et al. 2016). Therefore, an explanatory study must be carried out to further understand BIM and sustainability in Lebanon.

Qualitative research methods are used to understand the motive behind behaviours and actions by focusing on interpretation and exploration of social or human problems (Sale and Thielke 2018). Researchers provide an in-depth understanding of peoples' attitudes

on various human behaviours. Furthermore, qualitative research is used to better understand a certain issue in order to develop a larger theory or generalization, because qualitative research produces explanations about specific phenomena and contribute to the development of new theories (Rosenthal 2016). According to Crescentini and Mainardi (2009), the difference between qualitative research and a quantitative one is the question and argument built around the research, where the question must be clearly explained along with all terms and theoretical constructs used by the researcher. In addition, the information collected using qualitative methods of data collection will be analysed differently than the methods used in quantitative methods. Supported by Yin (2013), qualitative research provides a natural approach, since the researcher is personally involved in interviews and practices seeking to understand and discover insight into the development of a new theory.

When looking into quantitative or qualitative research it is important to consider two major factors, the sample size and the method of collecting data. Boddy (2016) explores the importance of selecting the appropriate sample size for the research. Qualitative research does not involve statistical generalizations; therefore, it focuses more on the quality of the data collected rather than quantity. A simple case study may be sufficient to produce an in-depth understanding that pushes knowledge further, but still, one case study is not enough to call it a generalization. Referring to the fact that BIM has low implementation rates and low levels of awareness in Lebanon, limits the number of participants that could take part in this research. Moreover, sustainability itself has not yet become a mandatory building regulation in Lebanon, which also affects the number of participants that can take part in this research. The concept of BIM for sustainable construction in Lebanon requires further knowledge, examination, and understanding, hence, a quantitative approach does not meet the required standards to carry out this research. Therefore, a qualitative approach is more appropriate for this research.

4.3.1.2 Interpretivist Philosophy

Moving forward in qualitative research, selecting the proper philosophy is key to the success of the study. Looking at the definitions discussed in the previous section, interpretivism is the selected philosophy for this research. Interpretivism emphasis the

difference between human behaviour and physical phenomena, and in this case, successful BIM implementation is influenced by the surrounding environment. As demonstrated in the literature, developed countries have studied and analysed the importance of BIM and sustainable development for the past several years and are working on further expanding their practice, while in Lebanon BIM awareness levels are low, as well as, sustainable construction. Therefore, it is important to consider the environment and human involvement in this research. Furthermore, this research aims to develop new understanding and enrich knowledge on the use of BIM for sustainable construction, a concept that has been rarely examined in Lebanon. Thus, according to Saunders et al. (2009), interpretivism promotes researcher's involvement by entering the social world of the research participants and understand their point of view, and finally interpret the research material and data according to the circumstances.

4.3.1.3 Inductive Approach

Complementary to the interpretivism research philosophy, an inductive approach is convenient for developing the theory of this research. Inductive reasoning is based on collecting data to explore a certain phenomenon, in this case, exploring BIM implementation to enhance sustainable development, and then generate a theory, in this case a framework for implementing BIM in the Lebanese AEC industry. The following figure 4.2 will summarizer the adopted research method and approach.

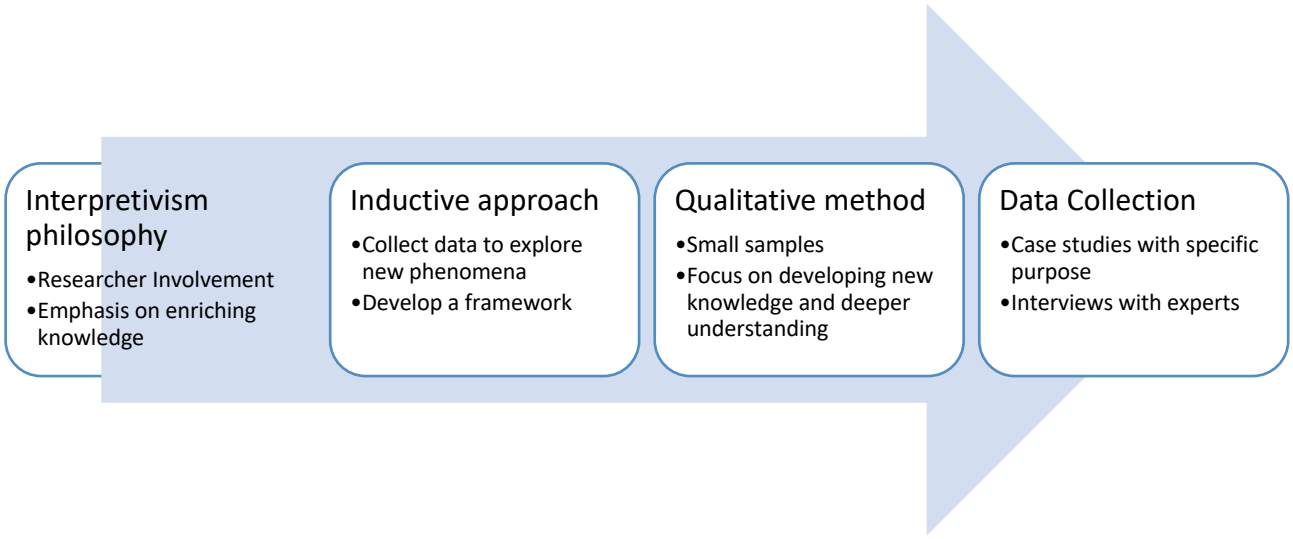

Figure 4.2 Adopted research methodology (researcher)

As shown in figure 4.2, data collection techniques are a key part of developing the research methodology. The following section will explore different types of data collection methods based on the philosophy and approach adopted for this research.

4.3.2 Data collection techniques

There are many existing methods for data collection, but they differ according to the level of researcher involvement and the number of participants required such as experiments, surveys, interviews, observations, and follow-up studies (Lähdesmäki et al 2010). It is important to differentiate between primary data and secondary data. The literature review is based on previously examined research, papers, and journals for reliable sources and good quality, hence this information is considered as secondary data. While data collected by the researcher is considered as a primary data source. In this case, the research is qualitative and should ensure a greater depth of understanding (Dudovskiy 2018). According to Tashakkori and Teddlie (2016), data collection methods in qualitative research can be semi-structured interviews, open-ended questionnaires, first-person observations, and case studies. However, for this research, the important factor that influences the method of data collection adopted is the knowledge of BIM. Therefore, it is important to establish a knowledge requirement analysis for BIM implementation.

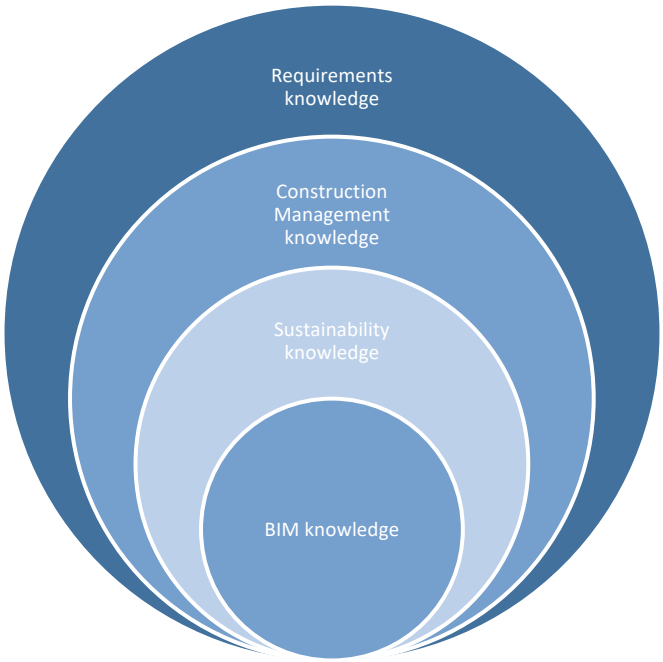

Figure 4.3 Knowledge Requirement Analysis diagram (researcher)

The purpose of a knowledge requirement analysis is to prioritize the knowledge required for collecting relative data. As seen in figure 4.3, BIM knowledge is the most important factor for proper data collection, followed by sustainability knowledge and construction management knowledge. Sources with high knowledge of BIM, as well as sustainability, play the most influential role in this research. However, it is important to keep in mind the important role knowledge of construction management has, but as represented in figure 4.3, the more specific the data required the smaller the expertise area is. As seen in the literature review BIM knowledge in Lebanon is relatively low, therefore, to expand the knowledge and for in-depth understanding, it is most fitting to build a case study with semi-structured interviews according to the knowledge requirement analysis.

According to Yin (2013), a case study investigates a real-life phenomenon whether single or multiple. Multiple case studies allow for in-depth investigation as well as analysis and comparisons between different situations. Referring to Majdalani et al. (2006), there are three major entities responsible for the decision-making process in a construction project, the director or client and is the owner of the project. Second the architect/engineer, the entity responsible for the design of the project, and finally, the contractor the entity responsible to carry out the work. This is based on a traditional delivery method. Therefore, to properly investigate the implementation of BIM in sustainable construction, a comparison between the performances of the three entities could have a significant influence on the outcome of this research.

4.4 Research Process

4.4.1 Literature Review and Previous Research

The initial stage of this research was to develop a literature review for identifying the main problems and gaps in knowledge. The design of this research can be broken down into three stages:

- Identifying the problem and theory development
- Building a case study and data collection
- Interpretation of data and evaluation

Extensive research was carried out to examine Building Information Modelling and sustainable development in Lebanon AEC industry. Selecting the relevant sources requires a systematic breakdown of previously conducted research in this field of study. Previous research examined Building Information Modelling extensively, as well as sustainable development and its importance for the future generation. The research also shows, that the implementation of BIM in sustainable development is a growing research area and have been heavily examined. Unfortunately, the studies have been examined on the level of developed countries, with very little light shed on developing countries. Focusing on Lebanon, previous research on sustainable development in Lebanon exists, but with little emphasis on the AEC industry. BIM has been gaining attention in Lebanon, however, research shows little progress in its implementation, as well as, slight incorporation with sustainable development.

Therefore, the selection of literature was based on identifying critical success factors for the implementation of BIM in the AEC industry, as well as, exploring different factors to enhance sustainable construction. Since Lebanon has little research in this field, there was a need to investigate other developing countries and develop a comparison in order to identify the problems and issues for the successful implementation of BIM to improve sustainable development in the Lebanese AEC industry.

In conclusion, an extensive literature review was carried out to examine BIM, sustainable development, and implementation in developing countries to design a case study, which will eventually develop a framework for this research. As shown in figure 4.4, the stages undertaken in this research, to develop a deeper understanding of BIM and sustainable development in the Lebanese AEC industry, leading to a framework for the successful implementation of BIM.

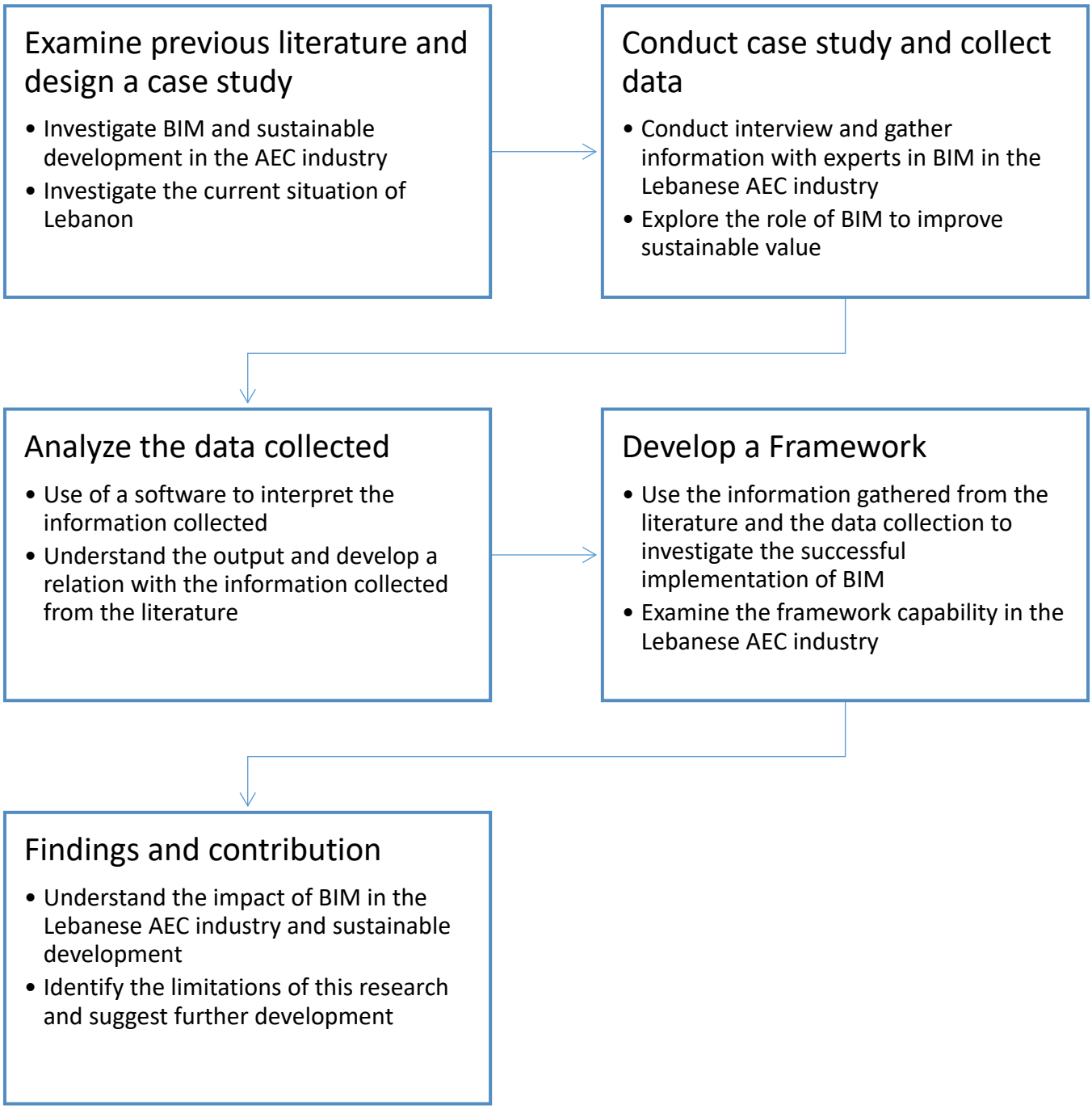

Figure 4.4 Stages of the research design (researcher)

4.4.2 Case study build-up and interview design

After extensive research, the literature review revealed the slow progress with Building Information Modelling in sustainable construction. The literature highlighted major issues with the successful implementation of BIM, especially in developing countries. This inspired deeper research to be carried out and examine different perceptions of BIM and improving building performance. For that reason, a multiple case study approach will allow the different context of this phenomenon to be furthered explored. According to Miles and Huberman (1994), a concurrent approach will allow for data collection and data analysis to work together hand-in-hand, where the data collection will focus on qualitative case studies.

To properly understand the different perspectives of BIM and sustainable development in Lebanon, a case study will be conducted in three different companies related to construction, with the focus being on the different entities who comprise the company.

- Company Directors: Lebanon has witnessed significant growth and increasing investments in the construction sector. Therefore, having the economic capability to invest in new construction projects while considering the cost of incurring BIM in these projects is curtail for selecting the appropriate directors. Moreover, having the knowledge and awareness of the benefits of adopting BIM, as well as supporting its practice presents a rare opportunity to build a case study relevant for this research. It is important to understand the perspective of a director towards BIM and sustainable development to improve awareness and justify its purpose for implementation and standardization in any construction project.
- Design Engineers: At the moment, design companies have the highest influence on the successful implementation of BIM. Lebanon has not yet reached level 2 BIM implementation, therefore incorporating project participants onto the same platform has not been achieved in the Lebanese AEC industry. However, BIM-based modelling is beginning to take off. The question remains on how do engineers consider BIM to improve sustainable development? The corresponding choice of the design companies should have experience with BIM design as well as sustainable design. The case study will aim to unlock BIM's potential in further

improving sustainable design by identifying the critical success factors for the implementation of BIM in the design firms of the Lebanese AEC industry.

- Contractors: Given that the knowledge on BIM and sustainable construction are relatively low in Lebanon, as well as, BIM maturity has yet to reach full cooperation of project participants, selecting contractors supporting the use of BIM may be the most challenging. Contracting companies find difficulty in changing the construction process, whether it's because of the immensely high cost or simply because of the fear of change. Nevertheless, it is important to examine contractors' opinions mainly due to the high impact on sustainable construction. During the construction process, high waste generation and pollution lower sustainability performance, however, BIM implementation could help improve that issue. Selecting the contractor is based on their support for a new innovative technique of construction as well as their expertise in improving building performance and sustainable construction.

Each case study consists of semi-structured interviews, where participants could share their experience and knowledge about BIM and sustainable development in Lebanon. Semi-structured interviews give the interviewee the opportunity to discuss the subject at hand freely, while remaining in the confidents of the key issues, thus the advantage of using semi-structured interviews is the ability of speaking freely in a specific topic. According to Hutchinson et al. (1994), interviews are a fundamental data collection technique in qualitative research. Interviews involve peoples' thoughts and ideologies towards a given issue, as well as, provide deeper knowledge about it. Henceforth, semi-structured interviews will provide the opportunity to communicate with experts in the field of construction management, BIM, and sustainable development aiming to achieve a definite conclusion on the impact of BIM in enhancing sustainable construction in Lebanon. Each case study will involve 10 to 15 participants from the above-mentioned companies, depending on their availability and collaboration, which will share their experience, knowledge, and opinion of BIM and aid in the aim of this research and developing a framework for the successful implementation of BIM in the AEC industry.

The interviews will focus of the construction process in Lebanon, current BIM protocol, sustainable development standards, and the overall construction process with or without the adoption of BIM, in accordance with the entity and the role it plays during the project lifecycle.

4.4.3 Data analysis technique

Once the data is collected, the next step will require the data to be analysed. Data analysis in qualitative research focuses on understanding broad data, which then must be reduced into significant patterns and in order to construct a framework from the essence of the revealed data (Patton 1990). According to Wolcott (1996), qualitative data analyses is based on three processes, description, analysis, and interpretation also known as data transformation. Field noted and interview questions are the first step in data analysis, they are considered descriptive analysis since the researcher at the moment is only gathering information to be processed later on. This is a challenging phase since the researcher will be exposed to a vast amount of data which will require careful filtration to be relevant to the research. The second stage will require a systematic approach to identify key findings, where the data will be expanded beyond description to account for an analytical method of understanding data. Finally, the third stage will make sense of the information described and analysed in the first two stages. Interpreting the outcome will result in a definitive conclusion for the research, with the results carefully examined.

In this research data analysis will be conducted in two manners. The first is a thematic analysis for every case done performed. After data is collected from every case study, each case study will be examined separately, and the information generated from each study will be analysed and interpreted. Software such as NVivo will help in storing, organizing, categorizing, and analysing the information gathered from every cased study. As well as aid in visualizing and interpreting the outcome of every case study. The second part of the data analysis for this research will focus on drawing a conclusion from the three-case studied previously examined. The second stage will present the results, conclusion, limitation, and future examination of this research.

Data analysis carried out in every case study will focus on relevant criteria of that case study. The data analysis will aim to link Building Information Modelling tools with

sustainable issues provided by every entity. Hence, it is important to analyse the sustainable issues provided by every entity separately and draw three separate conclusions. The final conclusion will compare and identify similar or different issues facing every entity and prioritize these issues with respect to the Lebanese AEC industry. These issues will then be mitigated with the introduction of BIM in the construction industry and therefore this research will aim to build a framework for the successful implementation of BIM in the Lebanese AEC industry for the growth of sustainable development.

4.5 NVivo Software

NVivo software is a powerful qualitative data analysis tool that will help organize and manage data in a smart and simple manner. With the ability to import text, email web content, audio and video files, NVivo is a great tool that can help transform words into measurable data. Nvivo focuses on creating a central data source that can collect information from several sources and group them into one cloud-based system.

Through semi-structured interviews, the researcher will gather the targeted information which will be later introduced into NVivo as text or audio depending on the interviewee's compliance. Using NVivo for the purpose of quantifying qualitative data, a thematic analysis could be carried out to generate a relationship between the data presented by different participants.

By using NVivo different themes could be created by coding the data that will create patterns and trends based on the questions and responses provided.

Finally, NVivo helps explore the data visually as it offers the option to easily create visual representations of the data such as word clouds, frequency charts, and comparison diagrams, that will help create themes and derive conclusions.

For the above-mentioned reasons, NVivo will be selected as the qualitative data analysis tool for this research as it offers all the necessary features needed for this study.

4.6 Ethical Consideration

This research complies with the code of ethical practice of Coventry University. Respecting the rules and regulations of Coventry University, an ethics form was submitted at the beginning of every academic year related to this research, therefore agreeing to terms and condition of presenting an ethical work. All information provided in this research is well referenced from respectable sources, truthful, honest, and accurate. The aim and objectives of this research were made clear to the supervisory team behind this research. Information gathered during interviews is private and confidential, as well as all individual participating were asked to sign a consent form informing them of their voluntary participation in this research. The validity of this research will present the level of accuracy between the result and the purpose of this research, whilst maintaining a professional and reliable conduct.

4.7 Chapter Summary

The research methodology highlighted the importance of selecting the appropriate philosophy, approach, and method to conduct the research. After defining deferent philosophies and approach, this research will use an interpretivist philosophy with an induction approach using a qualitative research method. The data collection process will focus on semi-structured interviews to build up several case studies to validate the use of BIM in the Lebanese AEC industry and explore its impact on sustainable development. The chapter also highlights the process of data collection and data analysis with the aim of developing a framework for the successful implementation of BIM.

Chapter V: Data Collection and Analysis

5.1 Chapter Overview

The following chapter is divided into two major parts firstly the collection of data through semi-structured interviews and secondly the analysis of data through NVivo software. The data collection introduces the company profiles and the role of the participants in their respective company. While the data analysis shows visual representations and relationships developed from the information presented from the participants' knowledge of BIM and sustainable development. This chapter summarizes all the gathered information on BIM and sustainable development in the Lebanese construction industry and presents the findings through visual representations using qualitative analysis software.

5.2 Interview Protocol

Pilot Interview: The pilot questions are to assess the level of BIM implementation and Sustainability knowledge of the participating company:

Table 5.1 Pilot Interview Protocol

Target	**Stage**	**Question**	**Purpose**
BIM and Sustainable development experts	Introduction	As part of research and development in the construction industry, what technological tools does this company actually use and intend to adopt?	Identify the level of technology used.
	Introduction	Apart from cost, time, and quality, does this company consider sustainability as a critical part during the design stage? How does it impact the construction process?	Identify the existing level of awareness.
	Understanding	Has this company considered the importance of Building	Establish a BIM understanding.

	Information Modelling as an innovative tool in the construction lifecycle?	
Understanding	Whether the company adopted or has not adopted BIM in the construction process, what are the main barriers and limitation facing BIM adoption in this company?	Identify the existing problems.
Conclusion	Focusing on sustainable development, does this company support the use of innovative technology, such as BIM, to deliver a suitable outcome for the project?	Establish the contribution for this research.

Interview Questions: Based on the answers provided in the pilot interviews, the company could either participate in the interview or it could not satisfy the minimum requirements needed for further investigation in this research.

Table 5.2 Interview Protocol

Target	**Stage**	**Question**	**Purpose**
BIM and Sustainable development experts	Understanding	Are the clients aware of the importance of sustainable construction and the role BIM could have on the outcome?	Identify the existing level of awareness.
	Mapping	What are the main sustainable aspects considered during the design phase of the project?	Identifying key components.
	Mapping	How can BIM aid in improving the design of the project and what is	Understanding the market.

	the expected outcome on the sustainable aspects?	
Mapping	What BIM tools are currently being used in this company, and what are the requirements needed to push for the next level?	Identifying key components.
Limitation	What could be considered as the main critical success factors for the company to achieve successful implantation of BIM?	Establishing the barriers and limitations.
Limitation	Can you provide a percentage of the company investment into BIM implementation and sustainable awareness? Can this figure be improved and what are the requirements?	Future direction for the research.
Framework	As part of developing a framework for BIM implementation, what BIM aspects could be utilized and linked with sustainable development for further research?	Validating the framework.
Framework	What are the key factors to achieve better sustainable performance in relation with BIM implementation and can they be mapped throughout the project lifecycle?	Validating the framework.

5.3 Company Profiles

5.3.1 Company Profile 1

The first construction company, which will be referred to as CA, is a leading privately-owned world firm with expertise in planning, designing, and managing large construction projects. CA is a billion-dollar firm which delivers complex construction projects worldwide and currently has around 300 offices around the world employing over 18000 employees. CA seeks excellence and growth in engineering, design, and management whilst developing a more sustainable delivery method on a global scale. CA is a major contributor to innovation and technology in the construction sector aiming to increase their productivity and add value to the company, as well as build a more collaborative platform for project participants. As a result, CA is one of the most prestigious construction companies in Lebanon and a priority firm to participate in this research.

Referring to the methodology chapter, specifically to the method of data collection which states that information will be gathered through semi-structured interviews to build a case study of 10 to 15 participants. Interviews in CA lasted about 45 minutes where interviewees shared their knowledge and expertise on BIM and sustainable development. The table below represents the project participants and their role in CA.

Table 5.3 CA Interview participants, role, and outcome

Interviewee	Role	Experience	Aim and Outcomes
CA1	Director	25 years	Understand the level of awareness, demand, and interest in BIM Investigate the reason behind the lack of investment in BIM Investigate the potential development of sustainable development
CA2	Director	15 years	A closer look into the barriers limiting the development of BIM or sustainable development Understand the limitation and lack of awareness

CA3	Department Manager	20 years	Investigate the limited investment on education and awareness development of BIM Understand the lack of BIM managers in the construction field
CA4	Procurement Manager	5 years	Lack of demand for sustainable construction is linked to limited funding and lack of resources Investigate the financial barriers limiting BIM implementation and Sustainable development
CA5	Research and Development Manager	10 years	Lack of awareness and knowledge is limiting the possibility of development and innovative construction
CA6	Project Manager	20 years	Understand adoption levels and requirements needed for the growth and development of BIM Investigate the barriers of BIM and impact on sustainable construction
CA7	Project Manager	15 years	Validity of sustainable construction and the influence of BIM on it. Understand adoption levels and requirements needed for the growth and development of BIM Investigate the barriers of BIM and impact on sustainable construction
CA8	Draftsman	5 years	Understand the reason for the limited BIM knowledge and the impact of BIM on sustainable design and construction

CA9	Draftsman	5 years	Understand the reason for the limited BIM knowledge and the impact of BIM on sustainable design and construction
CA10	Draftsman	5 years	Understand the reason for the limited BIM knowledge and the impact of BIM on sustainable design and construction

The interview targeted different levels of BIM experts for the purpose of evaluating different perspectives and understanding different opinions for the unsuccessful BIM implementation strategies so far. As shown in table 5.3, BIM experts with different roles in CA have different perspectives on BIM and its impact on sustainable development. As a result, different roles led to different opinions on BIM.

5.3.2 Company Profile 2

The second construction company, which will be referred to as CB, has a reputation of being one of the most professional, innovative, and technical expertise in the construction industry. The company is diverse carrying out procurement, engineering, design, and construction development activities internationally. The company's aim is to support local businesses, social activities, being environmentally friendly, and being proactive in socio-economic activities, which made CB a perfect fit to participate in this research. Its unique culture and training emphasize the company's reluctance to adopt new technology and innovation. Having one of the largest researches and development departments, CB is a major player in investigating BIM implementation and its impact on sustainable construction. CB also presents the opportunity to interview contractors and get a deeper insight into BIM activities during the execution phase in addition to the design phase. The company is highly diversified with offices based in 40 different countries and over 70000 employees. CB is always growing and has adopted many certifications such as being part of the Green Building Council, and specifically for this research, the Leadership in Energy and Environmental Design (LEED) certification which is currently being used in Lebanon as part of the sustainable construction initiative.

Similarly, to CA, interviews in CB lasted about 45 minutes with different project participants with different roles, represented in table 5.4.

Table 5.4 CB Interview participants, role, and outcome

Interviewee	Role	Experience	Aim and Outcomes
CB1	Director	30 years	Understand the level of awareness, demand, and interest in BIM Investigate the reason behind the lack of investment in BIM Investigate the potential development of sustainable development
CB2	Director	20 years	A closer look into the barriers limiting the development of BIM or sustainable development Understand the limitation and lack of awareness
CB3	Department Manager	20 years	Investigate the limited investment on education and awareness development of BIM Understand the lack of BIM managers in the construction field
CB4	Procurement Manager	10 years	Lack of demand for sustainable construction is linked to limited funding and lack of resources Investigate the financial barriers limiting BIM implementation and Sustainable development
CB5	Research and Development Manager	15 years	Lack of awareness and knowledge is limiting the possibility of development and innovative construction

CB6	Project Manager	20 years	Understand adoption levels and requirements needed for the growth and development of BIM Investigate the barriers of BIM and impact on sustainable construction
CB7	Project Manager	20 years	Validity of sustainable construction and the influence of BIM on it. Understand adoption levels and requirements needed for the growth and development of BIM Investigate the barriers of BIM and impact on sustainable construction
CB8	Project Manager	15 years	Validity of sustainable construction and the influence of BIM on it. Understand adoption levels and requirements needed for the growth and development of BIM Investigate the barriers of BIM and impact on sustainable construction
CB9	Draftsman	5 years	Understand the reason for the limited BIM knowledge and the impact of BIM on sustainable design and construction
CB10	Contractor	15 years	Understand the impact of BIM on the construction phase Assess the impact of BIM on sustainable construction and execution
CB11	Contractor	15 years	Validate the potential of on managing construction work Understand the impact of BIM on the construction phase

			Assess the impact of BIM on sustainable construction and execution
CB12	Site Engineer	3 years	Understand the potential of BIM on future construction execution works Difficulty with understanding BIM activities on site

The interview targeted different levels of BIM experts for the purpose of evaluating different perspectives and understand different opinions for the unsuccessful BIM implementation strategies so far. In addition, CB presented the opportunity to interview contractors and executioners to understand the different impacts of BIM between design and technical execution.

5.3.3 Company Profile 3

The third construction company, which will be referred to as CC, is a pioneer in the Lebanese construction industry. Being one of the largest design companies in the Lebanese construction sector, CC has heavily invested in the research and development of sustainable construction and worked on improving education, training, and awareness to support technology in the Lebanese construction industry. The company focuses on employee empowerment and work on providing the newest technology at its early stages. For that reason, CC is a prime candidate for investigating the impact of BIM on their performance. This company is heavily interested in improving the construction management process and is one of the major consulting partners in the Middle East region. The project management services provided by CC made it one of the leading companies when it comes to construction innovation. The company is currently working on a new initiative referred to the 360 perspective, which highlights the importance of 3D modelling and the benefits it presents to clients and customer satisfaction. Knowing that sustainable development is one the major contribution presented in this company, analysing both the impact of 3D design, which is the main component of BIM, with sustainable development is a key finding for this research.

Similarly, to the previous companies, interviews in CC lasted about 45 minutes with different project participants with different roles, represented in table 5.5.

Table 5.5 CC Interview participants, role, and outcome

Interviewee	Role	Experience	Aim and Outcomes
CC1	Director	30 years	Understand the level of awareness, demand, and interest in BIM Investigate the reason behind the lack of investment in BIM Investigate the potential development of sustainable development
CC2	Head of Research and Development	15 years	Lack of awareness and knowledge is limiting the possibility of development and innovative construction. Investments is sustainable construction and BIM levels.
CC3	Department Manager	20 years	Investigate the limited investment on education and awareness development of BIM Understand the lack of BIM managers in the construction field
CC4	Procurement Manager	10 years	Lack of demand for sustainable construction is linked to limited funding and lack of resources Investigate the financial barriers limiting BIM implementation and Sustainable development
CC5	Project Manager	25 years	Understand adoption levels and requirements needed for the growth and development of BIM

			Investigate the barriers of BIM and impact on sustainable construction
CC6	Structural Engineer	5 years	Validity of sustainable construction and the influence of BIM on it. Purpose of BIM implementation and impact.
CC7	Project Management Expert	15 years	Validity of sustainable construction and the influence of BIM on it. Purpose of BIM implementation and impact
CC8	BIM expert	5 years	Validity of sustainable construction and the influence of BIM on it. Understand adoption levels and requirements needed for the growth and development of BIM Investigate the barriers of BIM and impact on sustainable construction
CC9	Draftsman	5 years	Understand the reason for the limited BIM knowledge and the impact of BIM on sustainable design and construction
CC10	Draftsman	3 years	Understand the impact of BIM on the construction phase Assess the impact of BIM on sustainable construction and execution

The interview targets different levels of BIM experts for the purpose of evaluating different perspectives and understand different opinions for the unsuccessful BIM implementation strategies so far.

The following section will focus on identifying the companies and their knowledge of BIM and sustainable development. The section identifies three cases where large companies

are working on construction innovation and moving from 2D drafting to 3D model design. Based on the information gathered from the above-mentioned companies three case studies were developed to analyse the interviews carried out. As a result, the following section will develop and analyse the content of the interviews and develop these case studies.

5.4 Interview findings

5.4.1 Case Study 1: Company CA

5.4.1.1 BIM Definition

Building Information Modelling impacts every entity of a construction project differently, therefore, every project participant defines BIM in different terms. As a matter of fact, every project participant defines BIM in a manner that benefits them the most. For directors, BIM facilitates visualization and therefore could be considered as a modelling tool, but on the other hand, project managers define BIM as a tool to manage building information. This implies that every project participant has a different definition of BIM. In CA, directors CA1 and CA2 defined BIM as a platform to store the project information with easy access. Directors are interested in having access to project information, and BIM provides a simple platform for information exchange. According to CA1, in order to invest in BIM, it must simplify access to information when needed.

"Keeping up with technology is very important for every business, that is why I have considered BIM in my projects, but before investing in this technology I want to make sure it makes my life easier and provides me with the information I need"

For directors in CA, access to project information is their priority. In addition, they are interested in creating close cooperation that includes investors, engineers, architects, contractors, suppliers, and manufacturers. According to CA2, close cooperation facilitates information exchange for example entry or update of project information, which evidently makes decision making easier.

"It's all about developing key digital information management during the project phases"

As a result, directors define BIM as a platform to share project information with simple access for all project participants.

Unlike directors, project managers have a different definition of BIM. For project managers it is not just about project information and accessibility, instead, BIM requires more input than output. In comparison with directors, project managers are more interested in providing the information rather than accessing it. Therefore, for project managers such as CA3 and CA6, BIM is a technological innovation that aids in managing and organizing people, resources, and tasks. Supporting this claim, CA5 noted that for manager BIM is more about input rather than the output.

"Directors are only interested in the outcome of the project, but for us, the more information we introduce to BIM the higher the LOD and thus the better the outcome"

CA identifies LOD, as the Level of Detail working in BIM. The higher the LOD the higher the quality. The Level of Detail represents the information being introduced in the BIM project, for example, a BIM project with an LOD 3, means that this project is working BIM 3D modelling only, yet a BIM project with LOD 6 implies more information and more output such energy analysis and simulation. CA8, CA9, and CA10 are responsible for inputting the information of the project into BIM software and therefore are capable of identifying the LOD. However, for CA8, CA9, and CA10 BIM has a different definition than that of the managers. For them, BIM is a modelling tool used to create 3D models of projects and unlike directors or managers they disregard the concept of sharing information, collaboration, or management, instead, BIM focuses on visualization. CA8 carried on by saying that BIM is a modelling tool based on the LOD.

"We use BIM tools to create 3D models of the project and the more information we have the more we can input and therefore we have a higher LOD which makes the remaining tasks easier to visualize"

As a result, BIM in CA has different definitions for every project participant, which presents an issue when it comes to understanding the role of BIM in the company.

5.4.1.2 BIM Role

Theoretically, BIM does not contribute equally to all project participants. Directors fall under the category of non-BIM users, in other words, they consider themselves the entity with the decision-making power, regardless of the contribution for the AEC industry.

Directors, such as CA1 and CA2, highlighted the fact that they are not professionals in the AEC industry, and therefore they do not require software knowledge, so by that logic they consider themselves as non-BIM users. From there experience with BIM, directors found that the role of BIM in the AEC industry is to reduce fragmentation among the project participants. CA1 and CA2 emphasized the importance of BIM for creating a common platform with easily accessible information, thus scaling down the communication issues between professionals. Similarly, interviewees CA3, CA4, CA5, CA6, and CA7 agreed with the directors, that BIM's role in the company is to eliminate fragmentation, improve communication and collaboration between project participants. Nevertheless, CA6 and CA7 carried on by adding the importance of BIM on the decision-making process during construction. The information gathered in the BIM repository during design ensures the development and constructability of the project. The role of BIM considers the operation of the project within the constraints of time, cost, and resources invested.

"We consider BIM as a tool to facilitate the construction process, as most of the information we input help us assess the overall performance"

Similarly, draftsmen consider BIM as a repository of information. The role of BIM also includes visualization and 3D modelling. Referring to the work breakdown schedule, the lower the level of participant the more practical the role of BIM becomes.

5.4.1.3 BIM Benefits

The interviews identified several benefits for implementing BIM in the Lebanese construction sector. Every project participant correlates with specific BIM benefits related to their work requirements. Nevertheless, all interviews highlighted the importance of 3D modelling and identified it as the most beneficial BIM tool. Directors, managers, engineers, and architects stated that moving from 2D drawings to 3D modelling has been the major breakthrough in the construction industry today. The benefit of 3D modelling creates better visualization of the project thus facilitating the decision-making process, the design process, and the execution process. According to CA1 and CA2, directors are interested in facilitating access to information which BIM provides through a platform of data exchange.

"BIM 3D models help visualize our destination thus making choices easier"

According to project managers, 3D visualization aided in avoiding issues during the execution of the project. CA6 and CA7 highlighted that through BIM tools which provide the ability for clash detection, they were able to avoid any unexpected issues that might occur during the construction phase. Project managers consider the design phase of a project lifecycle to be the most critical and added on by saying "*the better the planning he simpler the construction".* CA5 concluded the interview by emphasizing the importance of BIM in the construction sector today and stated that BIM could improve the design of any project, save time and cost during construction, avoid any unforeseen execution problems, and organize the work clearly for all project participants.

CA8, CA9, and CA10 did not mention any managerial benefits of BIM, however, they did elaborate on BIM's visualization strength. From there experience, massive project modelled through BIM showed great potential for success during the design phase and even greater execution during the construction phase. BIM has facilitated the design process through the ability of 3D modelling and visualization, simpler blueprints could be made with a lower possibility of errors. Even when working at LOD 3, which is based on modelling information only, projects have shown bigger success than any 2D CAD-based design. Collaboration and visualization have been the primary boosters of BIM in the Lebanese construction sector. Research and development are still pushing the barriers and uncovering new functions of BIM in their companies.

5.4.1.4 BIM Barriers

When it comes to BIM implementation in Lebanon there are many aspects to consider, primarily the level of BIM the companies are working with. The BIM maturity levels describe different stages of BIM implementation, from which people can understand the performance of BIM in that particular industry. In order to properly examine BIM barriers in the Lebanese construction industry, there are two main ideas the interviewees should highlight, first being the current level of BIM implementation and second the barriers preventing the rise to the higher levels. According to directors, participants CA1 and CA2 agreed that BIM is a revolutionary tool that presents great benefits to the projects,

however, they considered themselves as new users of BIM in the Lebanese market. Thus, implementing high BIM levels is considered to be a huge risk for any directors.

"We appreciate the value of BIM and want to help it grow, but it is still being tested so it is unclear, and we do not want to be the guinea pigs"

The cost of implementing such technology is very high and the risks that come along are also very high, therefore the return on investment for any director is unclear, and this uncertainty reflects negatively on the BIM maturity level.

Uncertainty could be considered in two different aspects of BIM implementation. First was highlighted by directors as the uncertainty of the outcome. The second form was highlighted by the project managers when they referred to uncertain decisions that relate to the project. Apparently, BIM use requires certain information at the early stages of the project lifecycle that managers find irrelevant at the moment. CA4, CA6, and CA7 insisted that BIM is extending the project design phase for details that are irrelevant at the moment.

"BIM is forcing us to take decisions at the design phase that we are not sure of and as a result extending the design phase and delaying the construction process"

BIM requires a level of input that managers regard as irrelevant for the construction phase. Project managers consider the construction phase to be the most influential stage in the construction process, thus extending the design phase for unnecessary requirements is not improving the overall performance, on the contrary, it is slowing it down.

Time and money have been the major setbacks of BIM in the Lebanese construction industry. Yet there are several other social factors that are contributing to BIM's stagnant development. Social factors such as reluctance to change the construction process have been stated by several of the interviewees. In many cases BIM is regarded as a complication for example when considering communication, it is similar to learning a new language which many project participants consider time-consuming and an overall waste of time and energy for a minor improvement. Refusing to change the construction process is relatively the biggest barrier for BIM implantation in Lebanon.

"Why fix what is not broken"

Project managers consider some BIM attributes to be over-exaggerated and misrepresented which require a significant change in the construction process with uncertain outcomes that may not be as outstanding as expected. Participants CA8, CA9, and CA10 agreed that the lack of education and knowledge of BIM's potential, tools, and attributes is the main reason BIM lacks growth. In reality, BIM is neither taught on higher education or properly used in the market, which forces engineers and architects to resort to alternative methods to learn and grow there BIM knowledge. The younger generation is finding these alternative beneficial, however, more experienced practitioners consider the actual market rather than the futuristic one. At the moment BIM is being used for LoD3, which is basically modelling and inputting information in BIM software and according to the younger generation that is required in their current job description. The technological age gap has led to different views on technology and BIM in the construction process.

5.4.1.5 Critical Success Factors

Critical success factors are elements that are considered essential for the successful and facilitated implementation of BIM in the construction industry. Critical success factors in the Lebanese construction industry are poorly documented, hence the reason for CA to reconsider different factors for understanding the CSF for proper BIM implementation. Based on their experience, CA has broken down the CSF into different categories based on client needs. CA4 stated that due to lack of standardization CSFs vary on every project based on the owner's satisfaction, for example, certain projects require faster delivery while others require more detailing and visualization. As a result, CA4 proposed a systematic grouping of CSFs based on respective factors such as technological factors or human factors. Project managers such as CA4, CA5, CA6, and CA7 agree that the main categories of CSFs could be broken down into factors like technology, organization, process, and human. Each factor can be further subcategorized to achieve proper implementation success. Unfortunately, having the plan is insufficient for proper execution. Lack of BIM standards due to limited BIM knowledge in the Lebanese construction industry has set different standards in every company, leading to different

standards in the same sector. This can be assumed to be a problem in the process and human factor of the BIM CSFs.

5.4.1.6 BIM Potential for Change

When asked about the future of BIM in the Lebanese construction sector each interviewee provided insight on their opinion for BIM's potential. Directors found that BIM has great potential to change the project lifecycle, especially in the early stages. Having access to information and improving collaboration is the key factor for pushing BIM in the construction sector by directors. Nearly most directors agree that with the right standards and guidance BIM could be a great investment for any project. Nevertheless, the lack of knowledge has limited BIM potential on the Lebanese construction industry. Project managers who have been working with BIM found that many of the requirements are challenging and may not lead to the proposed outcome. In certain areas, BIM may lead to unnecessary complications which may be avoided using the traditional method. In any case, the process change requires an extended period of time, thus as research moves forward, uncertainty becomes clearer and the BIM barriers decrease, but on the other hand, BIM use may remain stagnant if certain critical success factors remain uniform. The younger generation of architects and engineers have shown faith in BIM's capabilities and have taken the opportunity to develop their knowledge and skill even though universities and schools do not offer BIM as part of their curriculum. Reluctance to change still hold BIM levels of development, leading to slow technological advancements in the field of construction in Lebanon.

5.4.1.7 BIM for Sustainable Development

The growing BIM potential in the Lebanese construction industry opened the door to explore different methods of construction to enhance the overall performance. The increasing demand for sustainable outcomes has shifted the director requirement for any construction project as stated by CA1 and CA2.

"Undoubtedly sustainability has become a priority in any project, construction or others, that is why we are trying to change our approach"

CA3 and CA5 agree that BIM unlocks new methods of design to consider sustainable development. Theoretically, that may be accurate, however, in practice that is not the case as stated by the project managers CA6 and CA7.

"The fact of the matters is that low sustainable performance in Lebanon is not reflected by the low BIM implementation, instead by the low demand for sustainable projects in Lebanon."

The Lebanese construction industry has witnessed an increase in the demand for sustainable projects, but overall the demand is still relatively low. Project managers are highly confident in BIM's potential for sustainable construction, however, knowledge and awareness on the importance of sustainable construction is not as sharp as expected. Similarly, to BIM, sustainable construction presents its own challenges of proper execution. Engineers and architects such as CA8, CA9, and CA10 work BIM at LoD3 and are very confident that they can work at higher levels if required.

"The more input we can introduce to BIM the better output we can generate, yet our clients still focus on modelling more than other aspects"

Introducing BIM in the Lebanese construction industry can achieve better overall performance, however, there should be a demand for better overall performance.

5.4.2 Case Study 2: Company CB

5.4.2.1 BIM Definition

Knowing that the construction industry has a reputation of being fragmented, CB is facing many challenges trying to close down the gap of miscommunication among its participants. Reflecting on one of the most common definitions of BIM as a process of developing 3D representations of a building with the capability of sharing information and facilitating the communication between project participants, CB has been working on developing a central database to integrate different aspects of their engineering practice. Due to a relatively low implementation rate of BIM in the Lebanese construction sector, CB highlighted the fact that they are pushing for a new innovative construction process, however, they are being held back due to the lack of demand for BIM projects in Lebanon. Nevertheless, some clients still pursue BIM tools in their projects. Investigating the reason

behind certain directors' demand for BIM, directors identified BIM as a tool to improve 3D visualization. Directors from CB stated that project visualization aids in better decision making, since visualization provides a more realistic perspective of the project layout than regular 2D CAD. Henceforth, directors define BIM as a 3D modelling tool capable of generating accurate models of the project, which directors consider a curtail aspect of construction projects.

"Better visuals help us make better decisions, which in return, help us save money and time for our project"

Similarly, to CA, directors in CB define BIM on the aspects that most benefit them, but project managers and engineers have a little more sight when it comes to BIM application and impact for future projects. Project managers such as CB6, CB7, and CB8, state that BIM's capability goes beyond simple modelling tools but are capable of creating a completely different approach for managing the project.

"We feed BIM input to get a bigger output"

Managers focus more on the information and its use to improve their project management skills. Undoubtedly, BIM tools can improve structural design and procurement methods as stated by CB3 and CB4 respectively, yet all project managers in CB agree that the definition of BIM is based on improving project management. As a result, the definition of BIM should not be regarded as a design tool but more on project management. LODs are the main component to create better BIM models, and the higher the LOD the more accurate the project execution will become. However, the elements of the LOD remain simple variables that can be altered or edited, however, project management is a skill that can be enhanced using BIM protocol.

"Introducing information is simple, managing the information is challenging and requires expertise"

Nevertheless, BIM's capability to create a better visual experience cannot be overlooked. As stated by CB9, BIM's modelling capability was a pioneering experience that launched BIM into the construction market. CB9 explained that the reason clients are interested in BIM is because of its visualization capability, which makes clients more involved in the

project. As well as, BIM's modelling tools have made the design process simpler in terms of work, yet more advanced in terms of output.

"Clients want models, managers want information. Without a good model, the information can't be introduced to BIM"

Contractors have a completely different definition of BIM compared to directors or designers. As stated by CB10 and CB11, contractors are more concerned with the execution of a project rather than the design. Regardless good execution comes after good design. Yet contractors focus on the feasibility and ease of the workflow, not to mention the safety of their labour and efficient use of their resource. Therefore, according to CB10 and CB11, BIM by definition is a tool to facilitate the workflow of the project while making sure resources are being used effectively and efficiently.

"Working onsite limits our access to technological advancements, therefore, we need the information in a basic fashion, yet the people with access to these technological advancements should make sure that our work on-site goes according to plan"

Site engineers such as CB12 are not very well included in the BIM circle, even though, theoretically BIM might facilitate the workflow on-site, site engineers are not concerned with design aspects and focus more on actual construction. Thus, leaving a technological gap in the definition of BIM as referred to by CB12, who had little to share about BIM and its implementation in the construction industry.

5.4.2.2 BIM Role

Directors, CB1 and CB2, agreed that the main purpose of BIM implementation in the construction industry is to create a better visual experience for any construction project. 3D visualization facilitates the decision-making process in both design and execution for example by selecting the better material or by proving a site layout for better distribution of equipment on site. Therefore, the role of BIM is to create a simulated environment for the project to create better design condition which eventually will lead to better and more efficient execution. Nevertheless, CB1 and CB2 also experienced their opinion on the value of the information introduced in the BIM model and the importance of having easy access to such information.

“As an investor in a project, I would like to see how and what I am investing in. So, what I want to see are models of the project which I can alter any time I want”

The value of information was greatly highlighted by the managers of CB. CB3, CB4, and CB5 emphasized the value of information sharing when they compared their experience in working with BIM related projects to non-BIM projects. Being department managers CB3, CB4, and CB5 stated that BIM related projects made their work much simpler and better, especially during the early stages of the project when there were many uncertainties and many changes to quantities and material.

“People still do not appreciate the value of time and how important it is to make the right decisions at the right time. In construction change is inevitable, but with BIM information is well organized, easily accessible, and smoothly altered which saves us a lot of time”

CB6, CB7, and CB8 have a little more experience when it comes to dealing with contractors and subcontractors. Therefore, their main focus was on facilitating communication between several entities of the project. As project managers, their job required them to keep records and deliver alterations to several project participants. As a result, project managers agree that the role of BIM in a construction project is to provide a single work platform to improve commination and information transfer between project participants, which agrees with their definition of BIM as a project management tool not only used for modelling.

Contractors such as CB10 and CB11 defined BIM as a tool to improve the workflow, therefore the role of BIM in a construction project is to eliminate clashes or unexpected design errors. BIM should deliver better shop drawing, better as-built models, as a result, eliminating unwanted errors. Furthermore, better design implies better execution, therefore better resource allocation and improved performance resulting in sustainable performance.

“BIM should give us what CAD could not. It’s smarter more advanced and more accurate. If this does not result in a better overall performance than investing in BIM is a mistake”

5.4.2.3 BIM Benefits

Since adopting BIM, CB has witnessed significant improvement in some aspects of its construction process. Even though the demand for BIM is still relatively low, CB has incorporated BIM in some aspects of certain projects based on the client's demand. Setting aside the expected outcome of adopting BIM in certain projects and looking at the facts, CB realized that projects that are BIM associated led to better overall performance.

Primarily, BIM-based projects showed better productivity, which was the main concern of director and managers. Almost every interviewee confirmed that working with BIM models instead of CAD drawings, have ended up in producing more efficient more accurate plans for the project. The fact that the client had easy access to information, as well as, managers had better control of the project, clearly had a positive impact on the project.

The fact that the general overall productivity of the project improved, generated better customer satisfaction as stated by CB1 and CB2, and emphasizing the direct relationship between productivity and client satisfaction in a construction project.

"The realization of knowing the project is going according to plan, made using BIM worth the effort and inspired more development"

The concept of better productivity was then elaborated by the project managers such as CB3, CB4, and CB5 who explained that this increase of productivity was a result of better scheduling techniques, cost estimations, quality control, clash detections, and facilitation of work. These improvements are basically the result of working with BIM.

"It is difficult to explain how BIM can impact a project, but once the clients see it, they understand how BIM is a game-changer in the construction industry"

From experience, CB concluded that BIM's potential exceeds their current knowledge and based on the response provided by the architects and engineers such as CB6, CB7, CB8, and CB9 Lebanon's construction sector is just understanding the first layer of BIM's impact at the moment. They realized that BIM-based projects did not only show improvement in productivity, yet in other aspects such as dispute resolution and project control. An advantage to any construction manager working on a project is having control

over the working force an unexpected advantage of incorporating BIM in the construction project that CB managers did not expect to have such an impact. As a result, BIM has shown to have greater potential that the Lebanese construction sector has not yet experienced.

From a contractor's point of view, BIM has not yet fully demonstrated great potential during the construction phase. However, CB10 and CB11 pointed out that due to BIM's capability of generating site-layouts and provide a better visual experience, the contractors could lower the uncertainties of project execution and prepare the site based on their preliminary estimations, where unlike CAD it was difficult to predict the actual site layout. Contractors focus more on the distribution of labour force and managing equipment on site. With the aid of BIM and 3D modelling efficient use of equipment and labour showed an increase in productivity, as well as, an overall improvement in the project environment.

5.4.2.4 BIM Barriers

According to CB, the adoption of BIM in certain construction projects has shown to have a major impact on the overall performance of the project. Despite these improvements, CB remains concerned with the demotivating factors that might hinder the BIM implementation process. Concerns over BIM that might inhibit the successful BIM implementation such as lack of skilled labour, lack of BIM awareness, and adoption time remain critical factors of construction evolution. Directors such as CB1 and CB2 are generally concerned with BIM flexibility and adaptation. In other words, CB considers BIM an advance complicated system which might not be easy to grasp especially for older more experienced employees with a reluctant attitude towards change. CB3, CB4, and CB5 support BIM adoption even though it might be difficult to understand. Yet, with training programs, people might have a different opinion. However, as stated by CB3, CB4, and CB5 these training programs require funding and time which no company is willing to invest in due to BIM's uncertainty in performance.

"Being such a fast-paced sector, construction does not offer time for growth. We rely on experience more than knowledge. That might be a reason why we are having trouble adapting to a new construction process"

Directors are also concerned with the initial investment and whether or not it is worth taking such risk, or at least in the Lebanese market which is considered to be slower than other neighbouring countries. Managers are also concerned with cost, yet they are more interested in the application and if it can be considered as user-friendly. From there experience, BIM is not an easy concept to grasp, which in time might slow the project progress.

When it comes down to BIM barriers, contractors seem to show the most concern and limitation to such aspects. First as stated by CB10 and CB11, knowledge of BIM in relatively low in the Lebanese market and trying to find subcontractors and suppliers who are familiar with such concepts is difficult. Keep in mind that CB is a large-scale company, while most subcontractors and suppliers do not have privilege. As a result, the lack of skilled labour and lack of knowledge in the majority of the sector is probably the main reason behind the lack of BIM implementation, not to mention lack of BIM initiative. Even though BIM is not being implemented, the fact that the market does not require the use of BIM hinders the initiative of considering the adoption from the beginning.

Finally, CB12 pointed out a relatively new reason for the unmotivated use of BIM related to the economic situation in Lebanon at the moment with respect to the market demand. At the moment, the younger generation of engineers is having difficulty finding well-paying jobs in the construction sector. With low market demand for BIM, employees familiar with BIM feel unappreciated, underpaid, and overlook. The market does not require BIM high BIM knowledge at the moment; therefore, salaries are being set based on traditional engineering knowledge without considering BIM. As a result, people who are investing their time to learn BIM, find themselves acquiring the knowledge without the benefits, forcing them to consider jobs outside of Lebanon or outside the construction sector. Managers understand the situation and yet they do not consider a solution such as training since recruiting people and training them to use BIM without an increase in salary will eventually force them to leave, and this will be considered as a bad investment.

At the moment, BIM's popularity is rising in the Lebanese construction sector, and as awareness rises, knowledge rises with it. People are investing their own time and money in learning BIM, yet the market still does not require or handle such supply of BIM experts.

5.4.2.5 Critical Success Factors

Identifying CSFs is the key to unlocking the successful implementation of BIM in the Lebanese AEC industry. However, due to lack of knowledge and previous experience, it is difficult to associate CSFs with BIM. According to CB, identifying CSFs requires careful planning and document execution. CB's approach to unlocking BIM CSFs is based on identifying different variables that influence the implementation of BIM in the Lebanese construction sector. Variables such as project information, financial resources, training, culture, experience, director's requirement, awareness, collaboration, and government involvement are a basic example of CSF variables that must be examined and monitored in order to properly establish a plan for the successful implementation of BIM. Each of these variables plays a major role in every project participant, and this was highlighted by the interviews. For example, directors CB1 and CB2 collaborated BIM application areas are industry-related factors such as the industry awareness levels with information sharing and access. They also focused on economic factors such as the availability of resources and qualified staff. According to directors, many BIM CSFs are divided into several factors with each impacting specifically a certain department. For directors, the size of the project, return on investment, client requirement, and coordination are the application of main concern. Managers identified more with parametric application areas such as time scheduling techniques and cost estimations. As well as, human-related factors such as training employees, improving the experience levels, and effective leadership. Similarly, the contractor identified the application of BIM for scheduling and cost monitoring. Furthermore, the contractor identified the importance of facility management, clash detection, and qualified employees. Similarities run in the BIM application areas, yet each entity is concerned with different factors of that application. Therefore, to properly identify the CSFs for the successful implementation of BIM, factors should be divided into several application area and assessed based on their contribution for their intended area. According to CB5, the CSF factors related to BIM fall into human, industry, project, policy, and resource factors. Expanding on these factors, as well as, identifying the contributing entity of each will set the path for proper BIM implementation in the Lebanese construction sector.

5.4.2.6 BIM Potential for Change

A major concern for BIM in the construction industry is its acceptance and standardization. Even though BIM has been receiving much attention, the fear of organizational change in construction companies has been a setback or a slow motive of BIM implementation. According to CB3 and CB5, BIM is a game-changer, unfortunately, the industry itself is not ready for that change.

"We have the technology, we have the incentive, but we do not have the clients"

According to CB1 and CB2, the fact that BIM will alter management styles keeps everyone on edge. BIM will change the way teams collaborate with each other, and the way managers handle the management system. BIM will also keep directors involved throughout the project lifecycle, thus encouraging better project value and long-term achievement.

From a project manager's perspective, even the contractors, CB7, CB8, CB9, CB10, and CB11 all agreed that BIM is the opportunity to encourage pre-fabrication and push towards a more organized, more time-saving techniques of construction. CB10 and CB11 also stated that BIM will also improve subcontractor involvement and collaboration. Nevertheless, BIM's involvement in the construction industry depends on the government perspective and effort to reinforce its use in construction projects. CB3 stated that only with government effort, BIM can truly excel and get integrated in the construction system.

"We can only push for BIM so much, but only the government effort can make our effort substantial"

Moving towards a full BIM implementation requires adaptive organizational change, and according to CB, BIM's potential to change the construction industry is massive. However, the attitude towards that change remains vague.

5.4.2.7 BIM for Sustainable Development

Based on the responses presented from BIM's potential to change the construction industry, CB3 and CB5 believe that with the right information BIM can be the tool that unlocks a new design process that can achieve more than just improving time scheduling

and cost estimation. CB believes that successful implementation of BIM can have a remarkable implication on sustainable development. CB4 stated that the same criteria that hinder the implementation of BIM, also lower the demand for sustainable construction such as awareness, knowledge, resources and so on…Yet one can be the solution for the other. The main argument for lack of sustainable project in Lebanon is that the demand and awareness are relatively low for sustainable projects. CB5 states that the reason for such low demand is the unfamiliarity with sustainable projects.

"The reason we don't see a high sustainable demand for a project is that clients believe it is complicated and requires more time and higher costs, when in fact if we worked with BIM it can be easily accounted for"

Similarly, to CA, interviewees of CB believe that sustainable construction is the output of a good design strategy, and instead of working on modelling to achieve LoD3, the design could consider more information and achieve LoD6.

Contractors CB10 and CB11 stated that the intention of building sustainable projects was never missing, however, the tool was. BIM is the bridge for that gap between traditional and sustainable construction.

"With access to information in a tool such as BIM, we can achieve more with less effort"

Managers CB6, CB7, and CB8 highlighted that BIM promises to deliver a project with better quality, a faster time, and lower cost. If we divide the concept of sustainable construction to its main pillars economic, social, and environmental, the conclusion states that the use of BIM is expected to deliver better sustainable outcomes. For example, the use of BIM will lead to better quality, lower costs, higher productivity, and higher value which implies that the use of BIM is resulting in better economic sustainability. The same could be said for environmental and social sustainability. BIM delivers better quality and thus will result in better environmental sustainability by lowering energy consumption, water consumption, improve waste management, lower noise pollution, CO2 emissions, aesthetic impact, and impact on natural resources. In addition, BIM improves health, safety, working conditions, community disturbance, and enhances employee skills, which is basically improving social sustainability.

Sustainability is a construct, which due to its low awareness levels is difficult to achieve or to convince owners of its value to the construction industry. BIM is a tool, which is not being put to proper use and has yet to demonstrate its full potential. Nevertheless, to achieve a construct, the proper tools must be applied. As a result, successful BIM implementation is a step in the right direction to achieve proper sustainable construction.

5.4.3 Case Study 3: Company CC

5.4.3.1 BIM Definition

Construction technology has a great chance to improve the construction sector, by improving the overall productivity and lowering the chances of failure. As a result, CC has taken on the responsibility of introducing BIM as a new construction technology in the Lebanese construction sector. Unfortunately, the results were not as expected. On a global scale, BIM has been receiving high attention, however, in Lebanon, the concept of BIM remains unclear and difficult to understand. In order to properly understand BIM, interviewees in CC attempted to define BIM based on their knowledge and experience. CC1, a director, defined BIM as a tool to improve visualization and communication in any construction project. The importance of improving visual models throughout the construction process is a key focus for every director. According to CC1, the point of investing in BIM is to help eliminate uncertainty throughout the project lifecycle. By improving the decision-making process, CC1 stated that they will eliminate uncertainty and reduce costs.

"At the beginning of every project we run the risk of skipping over important information, therefore we need to improve our visuals to see clearer and cover our blind spots"

According to CC1, the key elements of BIM are information and modelling. Unlike CAD, the models hold information that is critical to the success of the project. Interoperability has been an issue in BIM, but that does not imply the information is non-transferable. According to CC2 and CC3, BIM is still a vague concept in the Lebanese AEC industry, mainly because of the lack of demand for BIM-based projects. The level of technology being used at the moment makes it difficult to adopt BIM easily without the risk of losing information, changing the process, and investing large amounts of money with no reliable reward. As a result, BIM is regarded as a platform of integration for different project

participants, capable of reducing communication issues and facilitating the transfer of information. CC6 defined BIM as a tool for improving project design. Simply by moving for a CAD system which is based on lines and circles to a more component-based system, can produce a larger output of information whilst facilitating the process of integrating different software together.

"BIM has been a life-changer, and the best part of using BIM in design analysis is the fact that the models contain components of information rather than empty shapes"

According to CC8, BIM presents more than just visual aids, it is a hub for information gathering and sharing. BIM is a platform of several components that form a model, information-rich and easily accessible by all project entities.

5.4.3.2 BIM Role

BIM plays an important role in the Lebanese construction industry according to interviewees in CC. At the moment, BIM does not have a clear role in the construction sector in Lebanon, however, as stated by CC2, BIM has been getting more attention with every project. Thus, the role of BIM in the construction sector is to change its current approach from a traditional way to a more modern process. As highlighted by CC2, the introduction of BIM in any construction industry takes time, and due to the fact that Lebanon is not a rich well-governed country, BIM adoption is expected to take more time than usual. Yet, this does not imply that the role of BIM is negligible in Lebanon, but it implies that the role of BIM will take more time to define. CC3, CC4, and CC5 stated that the role of BIM in Lebanon at the moment is to improve awareness and knowledge on the construction process and open doors to new technological advancement which people believe do not exist in the Lebanese construction sector.

"The market believes that construction has reached its saturation point and there is no more room to grow, however, BIM has changed all of that. BIM as opened our eyes to a new way we could approach construction in the Lebanese market, and slow growth is still better than none"

The role of BIM is to change the construction industry from a 2D CAD to a 3D model, of smart information and simple collaboration. According to CC6 and CC8, BIM can change

the entire project scope. Rather than just focusing on reducing the project schedule and budget, BIM aids in looking deeper and achieving better quality while reducing time and cost. According to CC5, CC7, CC9, and CC10, the role of BIM is not clearly defined yet, because the market has little knowledge of it so far. BIM is an innovative technological tool in itself, therefore, its role in the construction sector is bridge the gaps of knowledge and open doors to new designs and execution processes. By improving visualization, communication, collaboration and several other aspects of the construction process, BIM will achieve great success and change the construction methods in the Lebanese market and achieve its role as an innovative tool for better project outcomes.

5.4.3.3 BIM Benefits

The difference in the perception of BIM implies that every entity is expecting a different outcome. Thus, BIM presents different benefits to different project participants. However, CC has considered BIM in different parts of the project lifecycle, and as a result, BIM benefits could be regarded along with the project's progress. In the initiation phase, CC1 explains that the benefits of implementing BIM will result in an optimized concept. Effective time management through improved conceptual designs, feasibility studies, site understanding, the accuracy of existing document conditions, and effective sustainable design will improve the construction process. Even though the demand for BIM input is high thus extending the design phase, the improved planning and resources management will compensate that extended time period in the design phase by lowering the time frame of the execution phase.

"It is true that BIM extends our design period, but we have to learn to look for the future. What we work on improving today will improve our performance tomorrow"

During the construction phase, CC5, CC6, and CC7 identified the benefits of BIM to have better construction management. Effective use of material, equipment, and labour could result in an improved overall project management experience. As a result, the construction process aided by BIM tools will produce efficient use of resources, site layout, and eliminate congestion as well as minimize health and safety issues. In the long run, CC2 and CC3 mentioned that BIM's recording capability will simplify the operation and maintenance of any project. BIM's ability to facilitate record tracking with ease if

access to any information regarding the project will make it easier, faster, and more accurate repair and maintain the integrity of the project. CC9 and CC10 concluded by restating the importance of 3D modelling and its impact on the project lifecycle.

"LOD is the key for any project success, the more details we input the larger the output."

Noting the impact of 3D modelling, affirms the importance of visualization for any project, thus highlighting the key elements of BIM relating the decision-making process along with the visualization of the project.

5.4.3.4 BIM Barriers

BIM technology is taking over the construction industry, however, according to CC1 this technology is moving at such a rapid pace the industry itself cannot keep up with it. As a result, forcing the industry to change caused a push back from engineers who might find this technology irrelevant. As a matter of fact, CC2 carried on by saying the more the industry pushed towards BIM the harder it was to change since the majority of engineers and labourers are not familiar with BIM and are reluctant to change.

"Technology requires time, call it a trial phase, we have not accomplished this phase yet so we cannot just force it on people who do not understand its potential. Construction is not a patient industry"

Referring to the saying that construction is not a patient industry, somewhat explains people's reluctance to change, which according to CC3 is the key barrier for BIM implementation. The reluctance to change comes for the lack of awareness of BIM benefits according to CC8. The initial high cost to adopt BIM with limited guarantees on the return of investment left directors and project owners in doubt about BIM. According to CC5, CC6, and CC7, the construction process requires a certain level of expertise, which cannot be found in BIM related project due to the low demand for BIM by contractors and subcontractors. The lack of standardization in addition to the legal issues associated with BIM adoption are also critical factors that reflect negatively on BIM implementation. CC6, CC9, and CC10 are expert designers who have years learning to use BIM as a design tool, and as stated by these interviewees that software interoperability has been a major problem with BIM implementation. The complexity of

BIM models along with the absence of a contractual agreement for BIM compatible software has made BIM use very challenging. In addition, project owners are not familiar with BIM, yet they request certain, but not all, entities to take part in BIM-based models. As a result, using BIM tools has become difficult and with such low salaries participants CC9 and CC10 identified BIM use in the Lebanese construction industry extremely difficult and may not be worth the investment. As of today, limited training programs are being scheduled to improve employee BIM knowledge, yet it is becoming a great deal in the market, forcing employees to invest in themselves, but it might not be worth the effort.

5.4.3.5 Critical Success Factors

Critical success factors for BIM implementation is a growing concern for any construction company in Lebanon. CC regards CSFs as the key measure of success for BIM implementation. According to CC8, CSFs are divided based on the participants' need, but that is not the proper way to approach establishing a proper implementation method. CC8 carried on by emphasizing the importance of grouping CSFs into major group categories and then breaking them down into single criteria. According to CC2, the low levels of awareness concerning BIM presents a challenge when attempting to group and then breakdown the factors. CC2 explains that CSFs should not be based on a personal need rather than on general development.

"The critical success factors are not based on the requirement of a single project participant such as improving time management, yet they should show a global aspect such as process factors which will then be divided into single components. Unfortunately, it is difficult to convince someone to look beyond his personal gain and to a more global picture"

CC7 supports this statement by clarifying that the low levels of BIM demand on construction project make it challenging to test hypothesis and grow when it comes to BIM implementation, which CC3 referred to it as a *"trial and error period".* CC9 and CC10 showed little knowledge about CSFs for successful BIM implementation and regarded as a managerial issue above their expertise level.

5.4.3.6 BIM Potential for Change

BIM is an opportunity for Lebanon to expand not just in the construction sector, but in the overall growth of the country. According to CC1, BIM might be the key that opens several business and investment opportunities for the Lebanese government. CC1 stated that Lebanon is a country heavily dependent on the construction sector and any advancements achieved in this sector implies an increase in the country's GDP and economic growth. Proper implementation of BIM will improve the construction process, thus lowering costs and opening up more investment opportunities in the Lebanese construction sector. CC2 stated that such development will also offer the opportunity to go beyond time and money and consider more sustainable construction. BIM might be the turning point the Lebanese construction sector needs to consider more advanced and sustainable construction projects. CC5, CC7, and CC8 agree that the construction industry is the foundation of the Lebanese economy, and with future projections, CC is expecting to take on more projects, which will require better technology to achieve better design and performance. As a result, BIM implementation today will result in substantial growth in the upcoming construction projects. As the market grows demand for sustainable projects increases thus demanding more from BIM and creating a more working opportunity for people investing in BIM knowledge today.

5.4.3.7 BIM for Sustainable Development

Based on simple observation, sustainable construction is becoming a standard in any construction project. Nowadays, projects that do not comply with environmental regulation are facing major setbacks, therefore, according to CC1 if BIM has the potential to achieve better sustainable performance, there will be significant rise for BIM implementation.

"Projects that do not comply with environmental regulation are being shut down, and knowing that BIM could help lower that risk clients will be looking for design firms that can handle both BIM and sustainable design"

According to CC2 and CC3, environmental regulations have set a new standard for construction. Unfortunately, when discussing sustainable construction environmental issues is only one of many concerns. In other words, due to limited knowledge on

sustainable construction when complying with sustainable construction environmental regulation are the main priority, however, there are many aspects such as social and economic that also should be considered during sustainable construction. Yet keeping the focus on environmental aspects CC7 and CC8 agreed that with BIM's potential to run energy simulation as well as advanced modelling design, carbon emission, energy consumption, waste generation, and overall pollutions could be diminished to a minimum level. BIM goes beyond time, cost, and quality by opening the construction industry to new methodologies and construction techniques that could not be adopted before BIM. CC4 concluded by informing about the importance of sustainable construction and the impact that BIM could have to push for a more socioeconomic and environmental future. CC9 and CC10 stated that with BIM 3D modelling tools it will be very simple to alter the design and create a more sustainable one, yet they were never put to such task due to lack of client demand. In which case CC5 stated that with such low knowledge on sustainability and BIM it is no surprise that clients find it difficult to invest in tools and concepts which seem farfetched to them. Nevertheless, all participants agree with the proper demand and the right BIM tools sustainable development could be the future of the Lebanese construction market.

5.5 Analysing BIM in the Lebanese Construction Industry

5.5.1 BIM Definition

On a global scale, Building Information Modelling has been identified as an innovative tool capable of changing the construction industry. However, based on the interviews conducted in the previous chapter, each case study identified BIM in a different light, especially when every participant presented a different definition for BIM. Based on these case studies, different project participants have a different understanding of BIM, as presented the following table 5.6.

Table 5.6 BIM definition based on project participant

Project Participant	**Aspects of BIM definition**		
Director	Information storage and accessibility	3D visualization	Coordination and collaboration
Project Manager	Improve project management	3D visualization	Create unified platform
Designer	3D visualization	Information storage and accessibility	Decision making process
Contractor	3D visualization	Create unified platform	Site layout and management

According to table 5.6, different project participants defined BIM on different attributes. There are four major project participants, directors, project managers, designers, and contractors. Based on their need to improve their project performance, BIM is denied as a tool that can provide the necessary attribute for its given field of use. The histogram provided in figure 5.1 represents the BIM attributes that have been commonly used for different project participants based on their highest frequency.

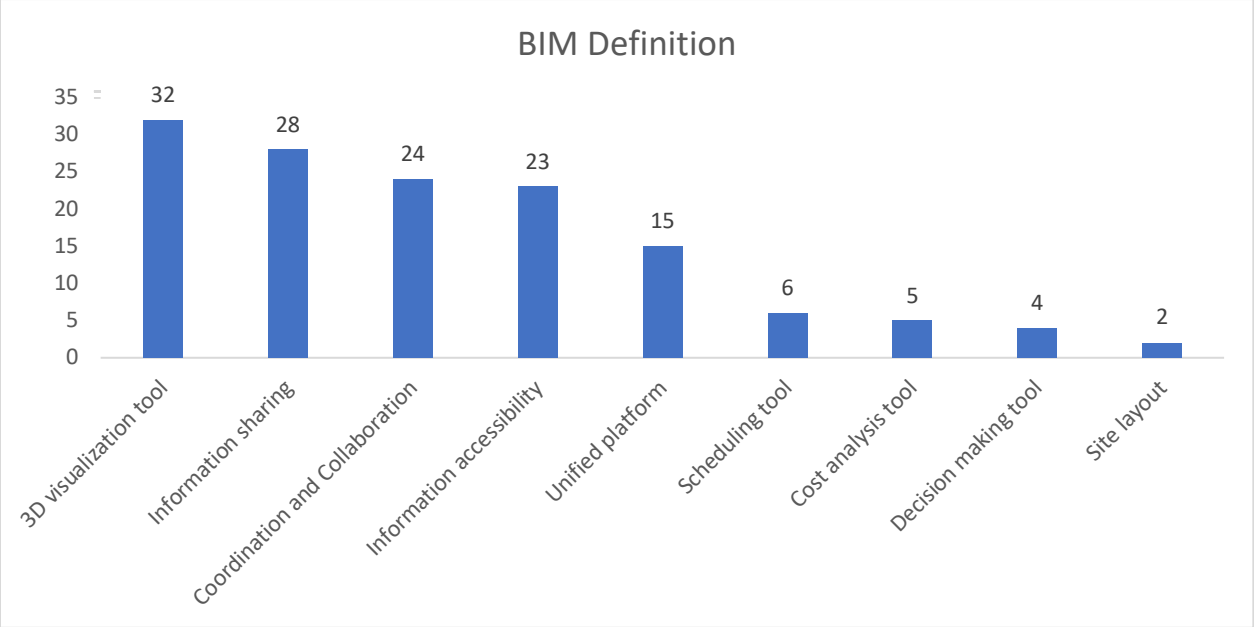

Figure 5.1 BIM definition based on interview frequency

Based on figure 5.1, in the Lebanese construction industry, BIM is defined as a visualization tool capable of generating 3D models of the project. In addition, these models are data-rich and can be easily accessible by different project participants. This definition can be interpreted from figure 5.1 which shows that the highest frequency of BIM definitions focused on visualization and information sharing. Referring back to the interviews, every case study highlighted the importance of LOD, which represents the level of detail in a model. The case studies established that the LOD is the level input fed into a BIM model and as a result, the higher the LOD is larger the output. The fact that the majority of interviews identified the LOD to be a key part of the BIM definition, justify the BIM definition to be model based. As of today, the LOD is the standard that defines the BIM model, therefore, as a result, the Lebanese construction industry complies with BIM as a modelling tool to improve visualization. The focus of this definition resulted in the following subthemes, represented in table 5.7.

Table 5.7 Definition Subthemes

Theme	**Subthemes**
BIM definition	3D visualization
	Project Information Accessibility
	Collaboration and Coordination

BIM Definition	1	26
3D Visualization	1	16
Collaboration and Coordination	1	14
Information accessibility	1	12

5.5.1.1 3D Visualization

The information gathered from the previous section shows that the Lebanese construction sector is working on improving the comprehensive nature of a construction project. The inability to visualize the target makes it challenging to undergo any alterations or improvements to the project. As a result, interviewees agreed that the first and most

critical definition of BIM is to provide a simulated environment for the project. The fact that project participants have a different definition of BIM does not imply a lack of knowledge, yet it opens up a variety of different opinions. The similarities between the case studies show that BIM definition is related to the defining entity and the project phase. Referring to the case studies that directors, managers, engineers, and contractors define BIM in a different manner that related to the project phase. Looking at a simple project life cycle consisting of the design, construction, and operation phases, 3D visualization plays a different part according to the project participants. The below table 5.8 demonstrates the use of 3D visualization for different project participants as a function of the project cycle.

Table 5.8 Impact of 3D visualization as a function of project lifecycle on different project participants

Project Participant	**Life-cycle phase**		
	Design	**Construction**	**Operation**
Director	• Conceptualization • Scope definition • Decision making • General and specific conditions • Requirements analysis • Initial drafts	• Monitoring activities and task • Comparing progress from design to as-built condition	• Monitoring the facility • Life expectancy analysis • Monitoring remote operations
Project Manager	• Schedule and cost planning • Design procedure • Detailed analysis • Decision making • Compliance check of building codes	• Monitoring activities based on time and cost • Detailing planning of activities happening on the field • Tracking contractor	• Monitoring project performance and facility management • Preparing steps for renovations or demolitions • Damage assessment

		percentage of work complete • Risk mitigation plan • Resource management	
Designer	• Detailed drawings • Specification and details • Client requirements • Run clash detection analysis • Constructability and ease of facility access	• Modifying shop drawing and alterations • Updating to as-built conditions • Quantity take-off	• Clash detections • Updating files and information • Space management
Contractor	• Detailed drawing • Material definition • Site layout • Sub-contractors and suppliers • Constructability and ease of facility access	• Detailed planning of activities happening on the field • Monitoring quality of built or fabricated items on site • Field work simulations • Resource management • Equipment positioning and navigation	• Maintaining performance and quality control • Damage assessment

Table 5.8 shows the impact of 3D visualization on different project participants during different phases of the project lifecycle. Hence, referring to case studies 1, 2, and 3 the directors, managers, designers, and contractors presented different definitions of BIM, yet the similarities between the definitions indicate that BIM is defined as a different tool during different project stages. Even though the three case studies showed that there is limited knowledge of BIM in the Lebanese construction industry, the majority of project participants agree on the BIM definition in their respective field. The fact that BIM presents different definitions in the Lebanese construction sector, implies unfamiliarity with BIM, yet this shows lack of collaboration between project participants, which is another aspect of limited capability in the Lebanese construction industry.

5.5.1.2 Project Information Accessibility

Project information could be categories into two types the input and output. Referring to case study 1, which reflects heavily on the importance of introducing the input to generate a larger output, in comparison with case study 2 and 3 which focus more on managing the available information. In actuality, the concept of introducing project information and managing the project information rely on the BIM tool itself, and from the interviewee's perspective, BIM is the tool that can manage the available information whilst aiding in generating new ones. In all three cases, directors found that having easy access to project information supports their involvement throughout the project lifecycle and facilitates the decision-making process. Whilst other participants found that managing information help create a better BIM model which will eventually result in better outcomes.

Figure 5.2 Project Information Accessibility Process

In order to ensure project accuracy and workability, project information should be managed and stored in a common platform, easily accessible by any project participant. In order to support the claim of defining BIM as a single platform of project information, figure 5.2 compares the information that should be introduced into the BIM platform with the information that could be generated from the BIM platform. As a result, the concept of creating a single platform, as stated by case study 2 and 3, could be achieved by involving project participants and proving access to all necessary information of the project. In addition, BIM's visualization and analysis tools could generate even more information for the project participants, as stated in case study 1.

BIM tools do not create a passive model, instead, they create dynamic systems which can be easily updated by project participants, so project management and tracking become effectively optimized throughout the project lifecycle. The information stored and shared revolves around the value of this information and its interoperability.

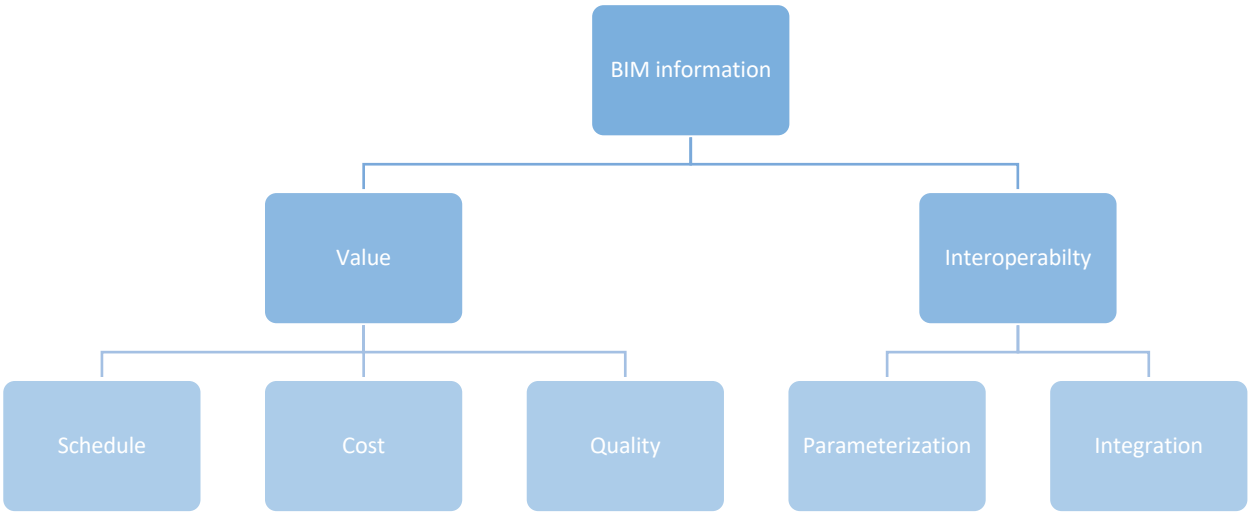

Figure 5.3 BIM Information Outcome

As represented in figure 5.3, BIM information value for the project, defined the participant's need for this information to improve on the project management process. The value of the information could be either subjective or objective, based on the

participants, yet impacts the project scope. Nevertheless, interoperability focus on the method of transferring the information itself, which involves creating criteria or parameters that set the stand for BIM integration. Interoperability sets to create a common language for the project participants, thus facilitating the process of accessing and sharing information on the BIM single platform.

5.5.1.3 Collaboration and Communication

The Lebanese construction industry's traditional approach of work execution separates project participants into different entities. As a result, BIM adoption will connect different participants and open doors for communication and collaboration. Based on the case studies, the Lebanese market is branching into BIM modules of design and execution, therefore, will eventually lead to a new form of open communication which according to case study 1, directors find necessary for integrating project information between project participants.

Communication in the Lebanese construction industry is highlighted through information exchange, organizational structure, project process, requirements, and access to information which reefing to case 1 and 2 is collaboration.

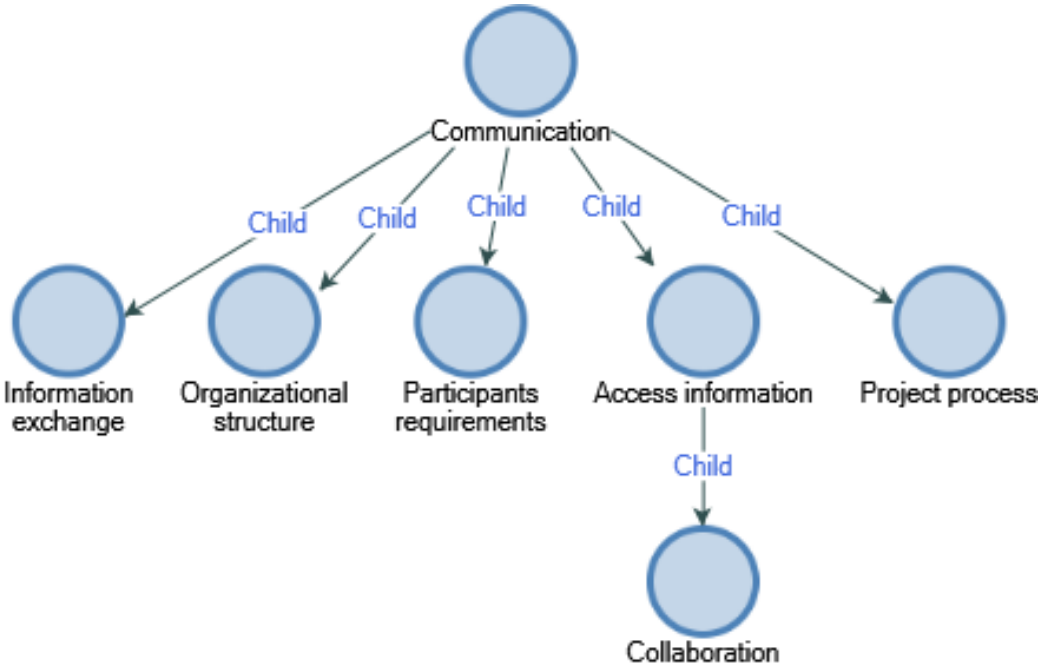

Figure 5.4 Relationship between Communication and Collaboration through Information Accessibility

Based on case study 3, communication and collaboration focus on the process of integrating BIM in the Lebanese construction sector. Therefore, by definition, BIM communication is the process of transferring independent project files to create a wave of linear communication between project participants. The project participants are basically the designer and the contractors as stated in case study 2, and even though they are separated for liability reasons, BIM creates an inter-organizational flow of communication. This flow of communication creates two parties, the sender and the receiver, where designers can send the models which contractors can easily have access to with all necessary modification and updates. As a result, BIM opens up transparency, and any negligence to comply with director requirements becomes a clear neglection from the contractor also referred to the receiver in that case. This process of open, free for all, flow of information exchange is what directors in all case studies defined as a BIM collaboration tool.

Unlike communication which was stated to a be a process of BIM integration, collaboration was referred to by interviewees as a human factor, where in order to achieve proper collaboration there should be an attitude change towards adopting BIM in the construction sector. Communication and collaboration are of equal relevance based on the case studies, whereby definition BIM adoption could create a single platform of open communication, where project collaboration and proper project management could reshape the process of project execution. Theoretically, all project participants involved collaborate through a chain of communication provided by the BIM platform. Unfortunately, theory and practice stand at different stages of BIM adoption, and as stated in case study 1 and 2, technical and personal problems hold back to full integration of BIM in the construction process. Choosing the form of collaboration in order to create a flow of communication still seems to be a challenge in BIM definition. However new technological advancements are opening the doors for proper BIM collaboration in the BIM process. As a result, collaboration and communication have become a milestone in BIM implementation, and a definite goal to be achieved and carried out throughout the entire lifecycle of the construction project.

5.5.2 BIM Role

Implementing BIM in the Lebanese construction sector will have a massive impact on the industry, as stated in case studies 1 and 2. Based on the information provided throughout the interviews, BIM is expected to reshape the Lebanese construction sector. The case studies highlighted several changes that will occur in the construction sector once BIM becomes fully integrated into the construction market. The high demand and the rush to proceed in adopting BIM as soon as possible shows that the market is already open to new, innovative, and process altering changes. From the information gathered from the interviews, BIM will change the role of many project participants. Some are process-based, such as director and managers, emphasizing that BIM will create a different construction process and redefine the characteristics of project management. While others, such as designer and contractors, found a more practical role change such as an improved design format and execution practice, as seen in the figure below 5.5.

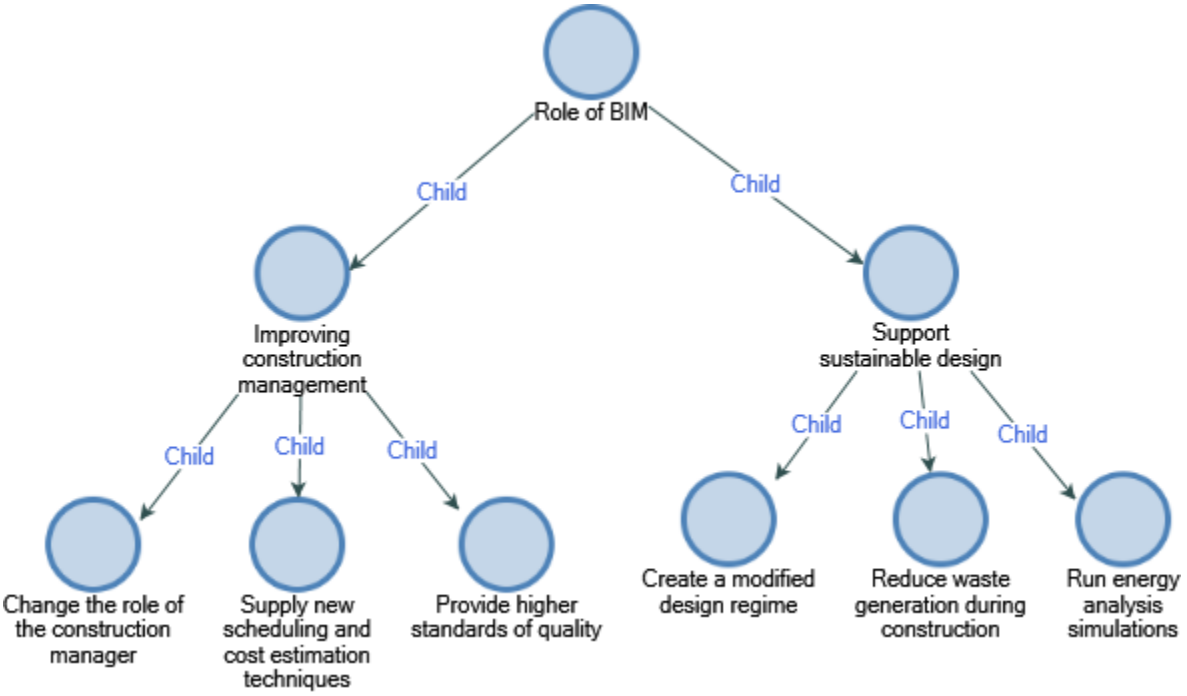

Figure 5.5 The role of BIM

Figure 5.6 NVivo Word Cloud

5.5.2.1 BIM role in changing the construction management process

Directors and project managers identified BIM as the tool that can close the gap between the fragmentations existing in the construction sector today. As highlighted in case study 1 and 2, BIM implementation will restructure the construction process, as a result, BIM implementation will change the process in which construction managers carry out their work on any project. The fact that BIM has become has a significant part of the construction industry, implies there will be significant changes to the process. Project managers agree that the traditional approach to carry on a construction project will no longer be sufficient, as the roles have been changed. Adopting BIM in construction will require an alternative approach for the project manager's duty, and this alternative approach creates the role of the BIM manager.

The position of the project manager will become less impactful once BIM becomes part of the Lebanese construction sector. The role of BIM in the construction industry, as stated in case studies 1 and 2 is to redefine the role of the construction manager and create new opportunities such as the BIM manager. The BIM manager will be the entity responsible for carrying out the new project manager role. With information exchange becoming a more progressive part of the construction process, the BIM manager will be

responsible to create the necessary platform for information exchange, which was emphasized a critical definition for BIM. Furthermore, BIM manager will be responsible for creating the network of communication, which was part of the project manager's role, however, BIM advancement requires a more detailed knowledge of the process.

The new BIM tools integrated into the system will require a different managerial style, compared to the traditional approach. New software and tool adoption imply a different set of working skills and understanding of the construction process. The role of BIM is to eliminate any construction management errors and generate new methods of delivering more accurate schedules and cost estimations. The BIM role is to eliminate fragmentations and errors already existing in the current process, in order to adopt a new more accurate process. Evidently, these errors will be eliminated thus providing the opportunity to create a higher standard of building quality. Which was introduced in case study 3, as the process of improving deliverables.

5.5.2.2 BIM role in delivering more sustainable construction

As case study 1 and 2 focused more on BIM changing the process of construction management, case study 3 focused more on the role of BIM in a practical perspective. Directors and managers found that the role of BIM could change the way construction management is conducted, however, designer and contractors found that the BIM role in the construction sector is to deliver a higher standard of construction. In case study 3, designer identified that BIM opens new technological interfaces that can run high analysis and go beyond time and cost. In case study 2, the contractors stated that BIM role is to make execution easier with better design elements. As a result, the role of BIM is to improve the productivity and performance of the project, in other words, a more sustainable project.

The role of BIM is to eliminate errors, not only on a process level, but on a more practical scale. BIM managers oversee work related to BIM models, which can be introduced in more advanced tools of building performance. BIM managers produce better and more accurate schedules and costs estimation, yet the role of BIM does not end there. More energy simulation, higher detailed analysis, and more pre-fabrication are simple examples that BIM could over the practical side of building design. Contractors' use of

BIM will deploy a better site layout, more efficient use of resources, and more accurate execution of work compared to the design. This new and improved relationship between designer and contractors changes the role of BIM in any construction sector. Eliminating delays and cost overruns implies there is an opportunity to deliver a higher standard of building value.

The role of BIM in the construction sector, in terms of practice, is therefore to deliver higher value for the construction project. Where value is defined in terms of shorter duration, lower costs, higher quality, and more sustainable performance. The relation between BIM and sustainable performance came to light in the case studies, as interviewees agree that the role of BIM in the construction sector is to narrow down the already existing gaps and open new opportunities for construction projects.

5.5.3 BIM Benefits

Building Information Modelling is showing great potential in the construction sector. With new and innovative methods of carrying out tasks, BIM has the characteristics of great change in the Lebanese construction industry. The case studies have shown many potential benefits of implementing BIM in the Lebanese construction industry. Based on these case studies BIM benefits can be divided based on the project participants and the role they play in the project. The case studies presented different project participants with different goals and expected outcomes of implementing BIM in the construction sector. Based on the information presented in the case studies, BIM benefits can be divided into four categories based on the project participants and there need for BIM in the construction project. The following table summarizes the BIM benefits with respect to that project entity.

Table 5.9 BIM benefits with respect to project participant

	Project Participant			
BIM Benefits	Directors	Project Managers	Designers	Contractor
Generating 3D models	✓	✓	✓	✓
Facilitate the decision-making process	✓			
Energy analysis and simulation			✓	
Information sharing and exchange	✓	✓	✓	✓
Management of project information	✓	✓		
Improve accuracy of as-built drawings			✓	✓
Clash detection		✓	✓	

Real time scheduling		✓		
Accurate cost estimation	✓	✓		
Facilitate building documents and approval	✓			
Create a platform of collaborative sharing	✓	✓	✓	✓
Improve resource management and planning		✓		✓
Improve site layout, health, and safety		✓		✓
Facilitating integrating sustainable construction	✓	✓	✓	
Minimize carbon emissions and reduce waste generation	✓		✓	✓
Improve investment opportunities	✓			

Improve overall project performance and deliverables	✓	✓		✓

The information provided in table 5.9 shows the benefits of implementing BIM in the Lebanese construction sector based on the interviewees' response in the case studies. Several BIM benefits apply to the same project participants, yet, the use of these BIM tools may differ. Nevertheless, the majority of interviews agree that BIM shows great potential to improve the overall performance of the project.

5.5.3.1 Director Benefits

For directors, especially the ones who are unfamiliar with the construction sector, BIM may change the way they perceive the entire construction industry. Construction is a complicated field, with a large number of tasks, participants, and many variables which are difficult to manage and keep track of. Directors initiate the project; they open up the bidding process and have the responsibility of carrying out the preliminary designs. With such high levels of uncertainty and a high number of variables, initiating the project presents a challenging level of risk for any project owner. As a result, the increasing attention levels of BIM, attracted most construction project directors, with the aim of eliminating uncertainties and improve the performance of their construction projects. Based on the information gathered from the case studies, directors in CA found that BIM implementation in the construction sector will facilitate information sharing and management, while CB found that BIM will improve the overall project performance by improving the management process and the overall customer satisfaction, whilst CC found BIM a tool that will result in an advanced construction process that will open new opportunities for more an enhanced construction sector.

Even though directors in different companies presented a different argument for BIM benefits, in reality, the process of achieving these benefits are the same. All directors agree that in order to achieve a better outcome, the process of carrying out the work and managing the tasks is the same. The most common benefit of implementing BIM in the

construction sector is 3D visualization, which based on the information presented in the case studies is one of the most practical solutions for most problems in the design process. Improved visualization implies a better decision-making process, thus better selection of project participants, contractors, and suppliers.

Creating a single platform of communication and coordination implies, that directors will have access to any information related to the project at any moment, which also results in the better decision and more importantly director involvement. BIM also creates more accurate estimations at the beginning of the project lifecycle, and since the information stored in BIM can't be lost, then this information will be adjusted and improved on throughout the project lifecycle.

In terms of aspects relating to the process improvements of integrating BIM in the construction sector, creating a platform of information storage and management as well as 3D models of the project, is of key importance for any director. However, from a more practical perspective, directors are interested in increasing their profits and market strength as a result integrating BIM in such large high-profile companies, attracts more customer and improves client satisfaction, thus giving these companies a strong competitive advantage on any construction market. Furthermore, investing in BIM as such an early stage in the Lebanese construction industry widens the opportunity to further improve the market requirement and meet any future demands, such as sustainable construction and facility management.

5.5.3.2 Project Manager Benefits

Project managers are the entity responsible to make sure every aspect of the project goes according to plan. Furthermore, they are the party responsible that the project meets the intended scope. As a result, the implementation of BIM will have a major impact on the managers' performance, since they are the people responsible to guarantee the successful use of BIM in the project. From the interview findings, the project managers in all case studies are intent on achieving the highest customer satisfaction, even if they do not always agree with the client's approach.

The fact that managers have to follow designers and contractors to make sure work is going according to the project schedule with no delays or cost overruns, is difficult especially when dealing with a large project with several designs, contracting, and subcontracting companies. Unlike directors, the reason behind generating 3D models of the project, or an accurate schedule, or cost estimation may not be for personal gain, after all, project managers have been carrying out the work before the existence of BIM. Yet, undoubtedly BIM will change the way managers approach construction management. With such high levels of technology and innovation such as clash detection, real-time scheduling, and unified platform, the role of the project manager has become much simpler. However, it still requires high levels of expertise and efficiency to carry out the work according to the estimated schedule and budget. On a global scale, BIM might not impact the project manager in a direct fashion, but it will alter the perception of the construction process. Thus, any project manager can use BIM tools to further improve the deliverables of the project and be open to the possibility to improve the quality of the project beyond the expected outcome.

5.5.3.3 Designer Benefits

Majority of BIM benefits focus on improving the design; therefore, the designers are the entity that benefits most from implementing BIM in the Lebanese construction sector. Unlike directors and project managers, the interviewees responsible for carrying out the design in their respective companies did not focus on the managerial aspects of BIM, however, they focused of improving the Level of Detail, or as referred to as LOD. The fact that BIM can create 3D models of the project provides the design the opportunity to work with further details such as class detection and running energy simulation. Even though creating a platform for information sharing comes with great benefits to the majority of project participants, designers found that since they are the people responsible for creating these models, working with the confines of a single module showed a great advantage when working with different designers from different field such as architectural, structural, electrical, and mechanical. The reason is that according to the case studies, creating a single data-rich model avoid crossovers and the change of obstructing someone's path, which is referred to as a clash detection analysis. Having the ability to

run this type of simulation saves time and eliminates unforeseen errors that might appear in the future.

Working with BIM encourages designers to create more advanced, highly innovative design models. Advance tools provided by BIM can improve the methods of creating schedule and cost estimation, furthermore, they can provide better visual before and during the execution phase. The relation between the design work and the execution work is critical, as a matter of fact, according to the case study 2, the relation between the design and the contractor sets the stage for the execution process. The ability to create as-built models and continues updating the project models while the contractor has access to these updates provide a faster and more sustainable construction method. The ability to generate more efficient and more sustainable design shows that BIM goes beyond improving the current construction process but provides the necessary tools to push for a new level of construction design in the Lebanese construction sector.

5.5.3.4 Contractor Benefits

In case study 2, contractors identified BIM as a tool that will change the construction industry from a design perspective. Nevertheless, they highlighted the fact that BIM benefits also apply to the construction phase of the project lifecycle. As a matter fact case study 2, shows how design and execution are linked together and states that the more accurate the design process the better the execution. Since BIM has been defined as a design tool the majority of the benefits apply the design change. However, having a single platform of collaboration which also involves contractors, implies that contractors have the same ease of access to the project information as directors, managers, and designers, which saves times and eliminates errors.

According to table 5.9, contractors found that having proper and up to date as-built drawing, will result in a much accurate site layout which reduces delays, whilst improving workers health and safety condition. A clear and well-defined project scope aids contractors in achieving a better project outcome, which is of key importance for any contractor to achieve good customer satisfaction.

Similarly, to directors, most projects in the Lebanese construction sector recruit an independent contractor, therefore achieving customer satisfaction is very important, as well as growing the company profile. BIM implementation will force contractors to adopt BIM as part of their project scope which a boost in the company profile, attract customers and investors, and grow their return on investment. The benefits of BIM for contractors relay heavily on facilitating and organizing the work carried out while ensuring worker health and safety, and most importantly improving the company profile by taking on new investors that are interested in a bigger and more challenging project and meet the demand on the new construction process related to sustainable development.

5.5.4 BIM Barriers

Building Information Modelling is reshaping the Lebanese construction sector. BIM is offering all project participants a chance to develop the construction process and improve the construction industry. Nevertheless, such great innovation always comes with great challenges and limitation. BIM implementation is a challenge to any construction industry, especially in developing countries such as Lebanon. Many barriers restrict the successful implementation of BIM, and from the examined case studies these barriers can be divided into three categories Economic, Social, and Environmental. Unlike the benefits of BIM, barriers and limitation apply to all project participants simultaneously, so to properly understanding the barriers of BIM, it will be beneficial to consider the impact of that barrier on the BIM implementation process rather than the party it influences. As a result, the table provided below 5.10 will introduce BIM barriers in the Lebanese construction industry.

Table 5.10 Economic, Social, and Environmental Barriers

Factor	Barrier
Economic	• Lack of investment in the BIM process • High initial cost for BIM software • Uncertainty for the return of investment • High costs for training programs and education • High salaries for people familiar with BIM, that are higher than the average employee • Low growth rate for the Lebanese construction sector • Transparency • Lack of director involvement
Social	• Reluctance to change and adoption of new technology • Long learning process • Lack of client demand due to low awareness and knowledge of BIM tools and processes • Lack of experience and skills with BIM in the workforce • Low levels of research and education • BIM is not included in the higher education curriculum • People familiar with BIM do not work in the Lebanese construction industry
Environmental	• Little knowledge and awareness on the impact of BIM on sustainable development • Lack of sustainable development tools • Lack of standardization and organizational involvement • No consideration for environmental parameters • Low BIM use in green projects • No framework for the implementation of BIM in sustainable construction

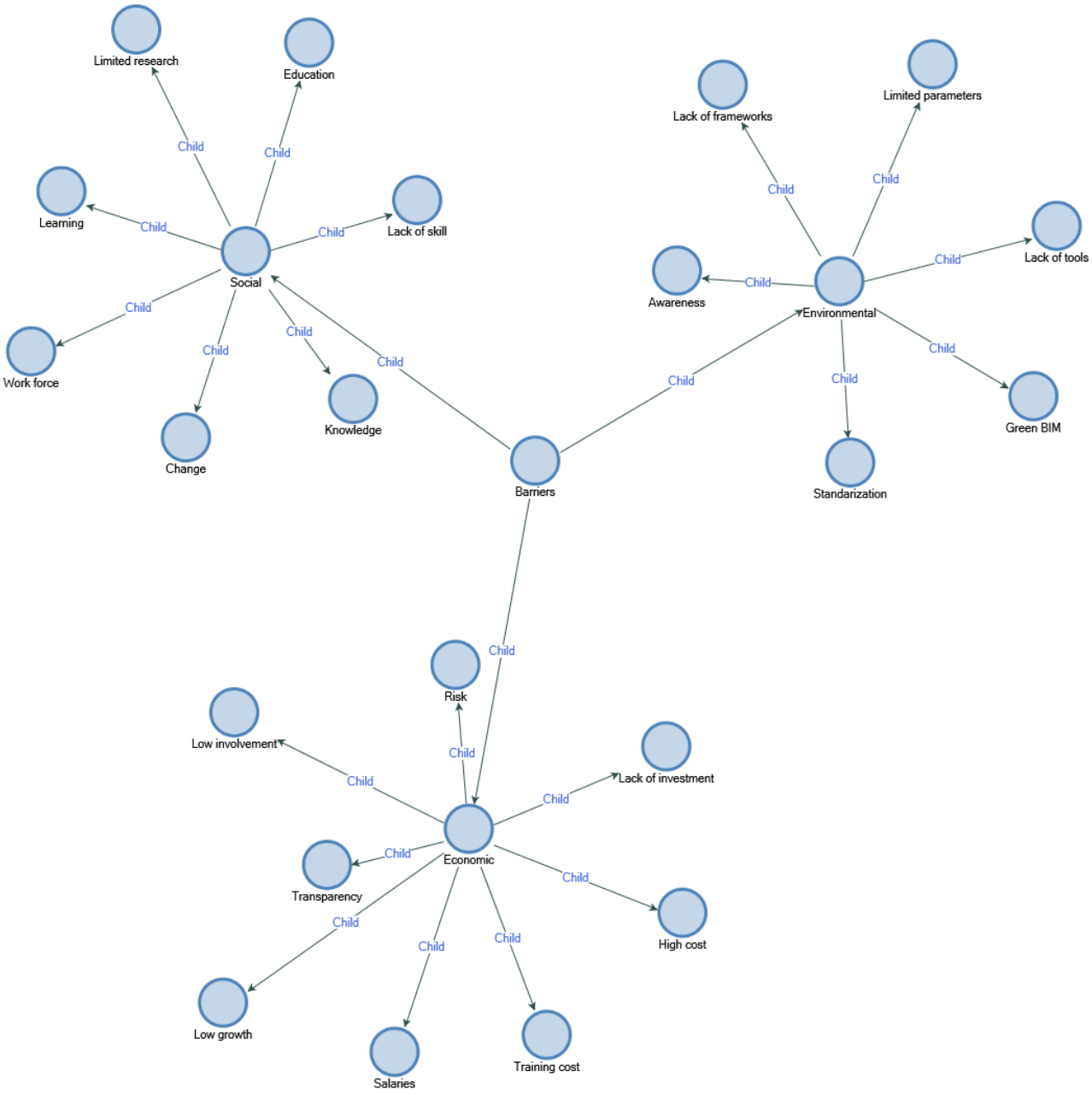

Figure 5.7 BIM Barriers Child Nodes

5.5.4.1 Economic Barriers

Lebanon is a country whose economy is heavily dependent on the construction sector. In other words, the performance of construction sector defines the Lebanese economic growth, therefore, being so heavily dependent of the construction sector shows that Lebanon's GDP is directly related to the performance of the construction sector and improving this sector will evidently improve the Lebanese economy. However, being a

developing country which such bad economic conditions show that the construction sector is not delivering the expected performance, which in return has forced the construction companies to take more severe precautions and hold their investments for more risk-free, low impact opportunities. Based on the information gathered from the case studies, companies realized that BIM requires a large financial investment, which does not guarantee any return for the company directors, implying that BIM has not been fully tested and may not meet the expected return on investment (ROI).

With such a fluctuating and unstable economic condition, directors find it inappropriate and unwise to invest in such a demanding system, BIM. The benefits may show that long term investment in BIM will result in significant financial improvements, yet based on the information provided by company directors, with such little guarantee it will be unlikely to attempt to fully invest in BIM at the moment.

BIM requires a dynamic change, whether software or labour skills, BIM will change the method of conduction financial estimation for any project, or even any fiscal analysis for any company. These changes require time for project participants to adapt, unfortunately, the unsteady nature of the Lebanese construction sector does not allow for this learning curve or testing phase. The Lebanese construction sector is a rapid fast-paced industry, with an active financial cycle, which implies there is limited space for change and delay. Managers found that BIM in the industry is still at its early stages, yet clients are starting to demand more BIM-based projects, yet companies refuse to take on this challenge, as a result, employees seek external methods of developing there BIM skills. These external methods require self-investment, and just like directors expect a return on their investment, managers, engineers or any self-involved participant expect such returns. Unfortunately, the financial situation in Lebanon does not present such opportunities. Case study 2, highlighted the fact that due to the low-income salaries for engineers and managers, participants familiar with BIM tend to leave the Lebanese construction sector and use there BIM expertise in other surrounding more economically stable regions. Furthermore, directors found that creating training programs to improve BIM skills only runs the risk of providing employees the opportunity to gain the required BIM-skills and leave to more high-paying jobs after the company has already invested in its employees.

The fact remains that Lebanon is a developing country with harsh financial situations, so undoubtedly, this created a corrupt work environment especially with contractors, and since BIM supports open and collaborative work, this means contractors have to provide a more open and transparent form of collaboration and communications, which does not seem to an easy task. Eventually, BIM will force contractors to do so, but this will not happen before a complete rejection towards BIM from contractors.

The rise in demand for BIM-based projects has put the Lebanese construction companies on high alert. Construction companies have found that BIM is an investment they need to consider, not to improve the construction industry, rather keep up with competitive markets. BIM investment is taking place yet at a slow and impotent level. The fact that the Lebanese economy is heavily dependent on the construction sector leaves little margins to work with BIM and its development.

5.5.4.2 Social Barriers

Building Information Modelling in the Lebanese construction industry is still a relatively new concept, in addition, it's a difficult tool to acquire. The construction, not just in Lebanon, but on a global scale has been known to have minor impacts on innovation and technology. When dealing with a developing country, neglecting technological development has created a traditional standard of work which is difficult to break out of, and even though BIM has been a massively researched topic in global markets, in Lebanon BIM is still a vague concept. As a result, the lack of knowledge and awareness on BIM tools in Lebanon has created this reluctance to change the construction process. The companies used to build the case studies are large scale companies, which have resources and the necessary requirements to initiate BIM in the construction sector. Yet, limited funding and involvement have been put to do so, which have led to the reality that construction companies in Lebanon are not fully aware of BIM's potential. This gap of knowledge shows that Lebanon is not a construction of research and development thus work is still being carried in a traditional redundant fashion. Case study 1 argues that BIM knowledge is common and high, but BIM practice is low due to low demand. Thus, in the construction market, there are 2 major players who contribute to knowledge and awareness, the client and the company. Companies are familiar with BIM, however,

clients are not, which in return makes BIM practice minimal with little or no experience of working with BIM.

Clients focus more on the end product rather than the process, however, case study 3 makes a valid argument when comparing the process to the product. However, the reluctance to change the process will eventually create the same product. This does not imply that labourers are not aware of BIM, yet it shows that there is a limited director involvement, and that market does not have the patience to create a BIM learning curve. Every system when adopted requires a time for testing and learning, but since BIM has a steep learning curve, construction companies in Lebanon are open to introduce technological advancement. Unfortunately, neither do higher education institutions. Traditional working methods are the result of traditional learning methods. BIM is not part of the higher education curriculum, thus BIM as of today, is not a requirement in the market. In reality, it is becoming so, thus creating a grey area of knowledge, research, and development. Low education in BIM leads to unskilled labour, which in return will result in low market demand. Yet when the demand starts to increase this means BIM is becoming a major contributor to the Lebanese market, yet the unskilled labour remains the same level. Reverse engineering the situation shows that there is a missing link between education and professional practice. As a result, prospective engineers and competent managers find the Lebanese construction sector weak and unappealing, thus seek opportunities outside the Lebanese industry, lowering the value of skilled labour and the overall value of the market.

BIM stands to be a market changer, which will create a new supply and demand curve, and based on the information provided in the case studies, the Lebanese market is reaching a threshold where it will no longer be able to supply the slow rising demand.

5.5.4.3 Environmental Barriers

With the Lebanese construction sector facing difficult financial situation, as well as, limited resources to change the current situation, environmental concerns do not seem to be a priority for companies in the Lebanese construction sector. Unlike more developed countries where environmental regulations have become a legal requirement for any construction project, in Lebanon lack of standardization, as well as, limited knowledge on

the value of sustainable development, with no awareness of the BIM impact on sustainable construction, have led to deterioration of natural resources as well as high levels of pollution.

The limited knowledge and experience in sustainable and green construction, in addition to the limited tools and analyses carried out in the design phase of construction project in Lebanon, have built an unsuitable toxic environment for the industry and its participates. As a matter of fact, as carbon emissions and pollution rise, concerns towards sustainable construction decrease. The fact remains that due to limited skills and knowledge, the Lebanese construction industry cannot visualize the negative impacts booming in the sector.

BIM offers tools and alternative approach to traditional construction methods, which might minimize the environmental consequences in the Lebanese sector. Yet the inability to value sustainable construction has plunged the value of BIM. As a result, the rush to adopt BIM in the Lebanese construction sector is relatively negligible and the continuous use of traditional methods, with overconsumption of natural resources, continue to prevail in the Lebanese construction industry.

5.5.5 BIM Critical Success Factors

Critical Success Factors are the most important principles to consider for the successful implementation of BIM. The case studies carried out identified several CSFs that will result in the proper use of BIM in the Lebanese construction industry. Based on the information provided form the case studies, CSFs are divided into many categories that are still not clear at the moment. To properly identify the CSF for the BIM implementation in the Lebanese construction, the first step is to identify the categories in which the factors fall under. From the information provided by the interviewees, there are five main categories which CSF fall under: Human, Industry, Project, Process, and Resource. Each of these categories presents its CSFs, which can be seen in the following table 5.11.

Table 5.11 Categories of CSFs

Factor	CSF
Human	• Communication and Coordination between project participants • Proper team build up, training, and education • Proper project scheduling during project execution • Social acceptance
Industry	• Technological Involvement and innovative design • Compliance with government policy and regulation • Involve sustainable planning and design • Update recruitments and standards
Project	• Clear project scope, plan, and control • Director involvement and participation • Managing external project risks • Extend commission period and account for facility management
Process	• Project management method and evaluation • Use of innovative design and modern execution method • Run early 3D clash detections, energy analysis, and site layout simulation • Adopt 4D scheduling and 5D cost estimations
Resource	• Designers capability and accuracy • Proper fund and supply chain management • Facilitate information exchange and management • Eliminate waste and minimize overconsumption of resources

5.5.5.1 Human factors

Part of the successful implementation of BIM in the Lebanese construction industry is altering the peoples' perspective of technology in the construction sector. Therefore, a key factor to consider when implementing BIM is the human factor, which emphasizes the importance of people and the role they play in adopting new technology. New technology implies new methods of work, thus new knowledge and skills required. As a result, selecting the process of selecting the project participant has become different, and the participants themselves are now responsible to improve their skill set to match the new project requirements. It is the responsibility of the project manager to build a competent team which can quickly adapt to change and have the capability to learn new BIM technologies to carry out the work properly.

A team who is exposed to new technology and knows have to benefit from such innovation can achieve more simply because they understand the importance of working as a team. Collaboration and coordination have been the main building blocks of BIM in the construction sector. Building a single unit that understands the importance of sharing information and collaborating together, knows that to adopt BIM technology is to work in a single platform of open information sharing. This form of collaborative work will initiate the concept of BIM in the Lebanese construction sector, as collaboration and communication are the main benefits of BIM in construction. Moreover, the implementation of BIM will generate more effective planning and scheduling during the initiation phase of a project and thus will prompt clients to consider more BIM project. Nevertheless, the main contributor to BIM is the construction market itself. As long as people find BIM difficult and unpractical it will always be cast aside. However, advertising BIM and its benefits will set a different mindset in the market and show its value in a construction project. In that case, people will be more accepting of the fact that BIM will change the construction industry and show a larger initiative for implementation.

People are the main component of human factors. The collaborative work is based on their acceptance of BIM. As knowledge and awareness remain low people will not be accepting of this new system. However, convincing them otherwise will be a major set forward for the successful BIM implementation.

5.5.5.2 Industry factors

Implementing BIM in the Lebanese construction sector requires an overall rehabilitation process for the entire industry. Thus, the CSFs that influence the sector are referred to as industry factors, and are the ones related to changing the industry itself. The traditional methods used today cannot support the use of BIM, as a result, the industry must change several processes to be able to correctly and successful adopt BIM in future construction projects. Unfortunately, the industry factors are not linked to a single organization, yet they are linked to the full market, which shows that this is a time-consuming process which will require many or even all companies to change their profile in order to keep up with BIM adoption. Knowing that Lebanon is a county with little capabilities and little margin for flexibility, changing the industry itself will be very difficult, especially when it comes down to adopting and investing in new technology. Such large-scale changes require government support to force companies in the industry to re-evaluate their systems. Given the freedom of choice companies in Lebanon will not invest in BIM unless it is financially beneficial. For that reason, the government should instate new regulations, laws, and building codes that comply to BIM standards. In that scenario, companies will be forced to consider BIM in their future projects. Unfortunately, with such limited knowledge and experience with BIM, restructuring these laws will take a long period of time, especially for guaranteeing financial growth.

The government should consider reassessing the qualification of the people responsible to carry out these regulation changes. BIM has shifted the market requirements, therefore initiating the process of implementing BIM requires a different set of skills and knowledge than the one already existing.

One of these skill sets should consider the influence and importance of BIM on sustainable development and take into consideration the opportunity to build more sustainable building environment. Industry changes will set the stage for BIM use in any construction company and any construction project.

5.5.5.3 Project factors

Project factors are related to aspects of the project itself, and to properly implement BIM in the Lebanese construction sector, one must consider its impact on the overall project outcome. It is important to link project aspects, such as scope, schedule, and cost to BIM attributes. The purpose of BIM is to produce a better overall project deliverable and experience, therefore, the CSF that identify with project factors are basically the ones that show the influence of BIM in the construction industry.

A project is defined as successful when it has a clearly defined scope where all project participants can be involved, in addition, the project meets its intended schedule without delays and without exceeding the budget. The criteria to define the project success are the BIM aspects of improving the construction process. Simplifying the work to create a simple environment with higher participation lower risks and a clear destination.

Stockholder involvement in any construction project supports the use of technology and innovation, as well as, result in better project execution. By analysing external factors and lowering the levels of uncertainty, projects will eliminate unnecessary costs that can be used to invest in more technological and innovative tools such as BIM that will further develop quality and aid in creating more opportunities for the future such as facility management, which will improve the operation and maintenance phase of the project.

The proper study of the project can create the opportunity to improve the use of BIM, which in return can improve the overall lifecycle of a project.

5.5.5.4 Process factors

The process factors are related to the methods of executing the project. The main CSFs for BIM implementation are related to the project execution strategies. Unlike the Industry and Project factors, Process factors are an in-depth representation of the project delivery process. BIM is a process changing event, in other words, it sets a new technique of carrying out the tasks. Increasing the importance of project management techniques will ultimately bridge the gap between design and execution. The process of moving from 2D CAD to a 3D integrated data-rich model shows a potential of reshaping the management strategy. Updating management process changes the way a project is carried out and

delivered. Based on the information provided in the case studies, majority of projects in Lebanon suffer from delays or cost overruns due to incompetent management. As a result, the process of project delivery can now focus on 3D visualization, 4D scheduling, and 5D cost analysis, thus opening the doors for a better future in construction.

Process changes require the acceptance and involvement in new technology, a limitation that the Lebanese construction industry is very familiar with. However, director involvement and readiness to take action can ultimately change the process on a local scale, which eventually can be developed to a more global market. Social acceptance along with process development are the initiation of the BIM implementation strategy. Unlike industry factors, this might night require as much time to achieve as long as the resources are being used efficiently.

5.5.5.5 Resource factors

Majority of CSFs are heavily dependent on the effective use of resources. Due to the fact that Lebanon is not a rich country with very limited resources in the construction sector, effective and efficient use of resources is very critical in the BIM implementation process. In Lebanon, resources can be divided into three parts natural material resources, the labour force, and financial capabilities. When it comes down to work force, Lebanon lack of BIM education and awareness has left the industry in a blind sport towards innovation and technology. As a result, BIM implementation is difficult due to the lack of people capable enough to carry out the necessary task. Therefore, valuing BIM will give a more positive feedback when mentioned in the construction industry. Education is the key to improve the labour force and will eventually supply Lebanon with greater resources.

On a more direct approach, funding and financial stability have also been a limitation for BIM implementation in Lebanon. Financial resources are only present in large scale companies, and that can be seen in the case studies. Even though, BIM is growing subject, financial capabilities limit its expansion and development. As a matter of fact, financial resources have also limited natural resources, since Lebanon is not a naturally rich country. Due to unorganized construction, natural resources are being wasted with little or no value. This does not only impact technological development, but also eliminates sustainable construction, thus eliminating the need for technology and BIM adoption.

Managing resources is a critical part of sustainable construction and prompts a more advanced and stable management tool. BIM can be the tool that manages the resources and thus open doors for more sustainable construction.

5.5.6 BIM Potential for Change

The development and growth of BIM in the construction industry has been questionable, yet there is no denying the importance of using technology and innovation in any industry. Unlike the manufacturing, pharmaceutical, or transportation, the construction industry has shown little interest in adopting technology, but BIM has been able to change that perspective and encourage construction companies to initiate a change process to develop and expand the construction industry. In Lebanon, BIM is still in its early stages, however, the interest is growing. Based on the information gathered, BIM has been linked with big benefits and an impactful change in the construction sector. Nevertheless, many participants found negative consequences resulting from BIM implementation as can be seen in the following figure.

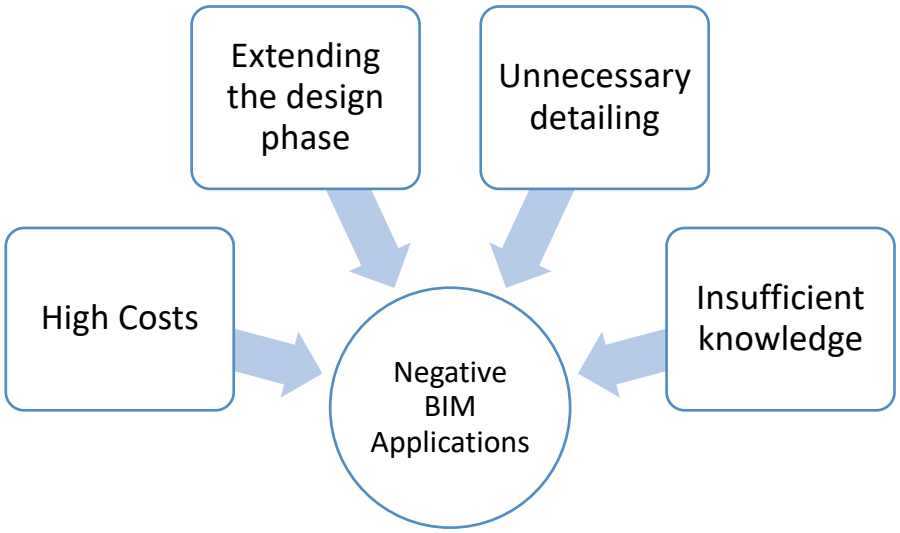

Figure 5.8 Negative BIM applications

Even with the negative effects of BIM, it has been a growing topic of interest. According to the case studies the big question with BIM is that "Do the benefits outweigh the losses?". At such early stages it is difficult to predict BIM's direction in the Lebanese construction sector. However, BIM has shown great significance as of today, mainly in

tow main areas. First, the management of construction project and second the demand for improved quality. As a result, BIM even at such early stages, has already had an impactful presence on the Lebanese construction industry, and as it progresses and matures, expectation shows significant changes in the sector.

5.5.6.1 Alter Management Style

Traditional management style focused more a linear hierarchy method of management, or a top to bottom approach, where a manager is responsible for a team and that team is responsible for another and so on. However, BIM requires a more collaborative form of management, since the hierarchy key is no longer the line of communication. BIM has a created a platform of collaborative sharing and as a result requires a more “hand on” management style. Managers are no longer responsible for a team, but they are responsible for whole platform. Communication between project participants is improving due to the adoption of BIM modelling tools, so managers now can redirect their attention from ensuring communication to a new task involved in the construction process such as 4D scheduling. The fact that BIM has removed redundant managerial tasks, opens opportunities to benefit from the extra time and create more effective tasks, for example by creating a single platform, BIM has eliminated the need for managers to create a communication line for project participants.

The point from creating a new management process is to eliminate unnecessary tasks, which are time consuming and a burden for construction managers. By eliminating redundant tasks, managers are free to focus on more meaningful issues. However, new tasks require new skills and a different knowledge set, so for the managers to carry out a satisfactory performance, it will require a commitment for improvement, which unfortunately based on the information gathered in the case studies is difficult to inspire in an older generation. Nevertheless, younger generations value technology and understand the impact that BIM can make on the industry, thus there is a noticeable difference in the attitudes towards technology and breaking the traditional cycle to update for a more modern managerial approach.

5.5.6.2 Support Sustainable Construction

The construction industry is a priority for the Lebanese economy, therefore, improving its performance will evidently lead to the economic improvement of the entire country. An increasing GDP offers more flexibility, and an ability to consider further investment and development. With such high influence in the Lebanese economy, the construction industry is an influential factor, thus improving the performance supports the cause of successfully implementing BIM in the construction industry. The outcome will present the opportunity to consider a better standard of performance and the focus will shift from time and money to quality. Quality in this scenario refers to a higher demand for sustainable construction. In other words, successful implementation of BIM, as of today, will improve the performance of the construction sector thus improving the Lebanese economy, and call for more investment in better quality construction.

As innovation pushes forward, the next step will focus on achieving better sustainable construction. Thus, the Lebanese construction industry will witness an increasing demand for sustainable construction. As part of that initiative, BIM will be a leading tool to aid in achieving better sustainable performance by improving the design standards, reduce waste and pollution, as well as aid in efficient use of resources. An in-depth look of the impact of BIM in sustainable construction will be carried out in the following section.

5.5.7 BIM for Sustainable Construction

A growing concern in the Lebanese construction industry is the lack of demand and awareness on the importance of sustainable construction. From the case studies, it can be deduced that due to lack of technological development and low overall performance achieving such high standards of construction is difficult. As a result, clients tend to focus more on time and money while neglecting quality and sustainability. The lack of technology and innovation has left the Lebanese construction industry stagnant, and the fact that BIM itself has low awareness levels in Lebanon shows little potential for sustainable construction. The relation between BIM and sustainability has become clearer, so due to lack of BIM implementation for many of the previously mentioned reasons, raising the quality of construction is difficult, as a result, achieving sustainable standards of construction has become farfetched and unachievable.

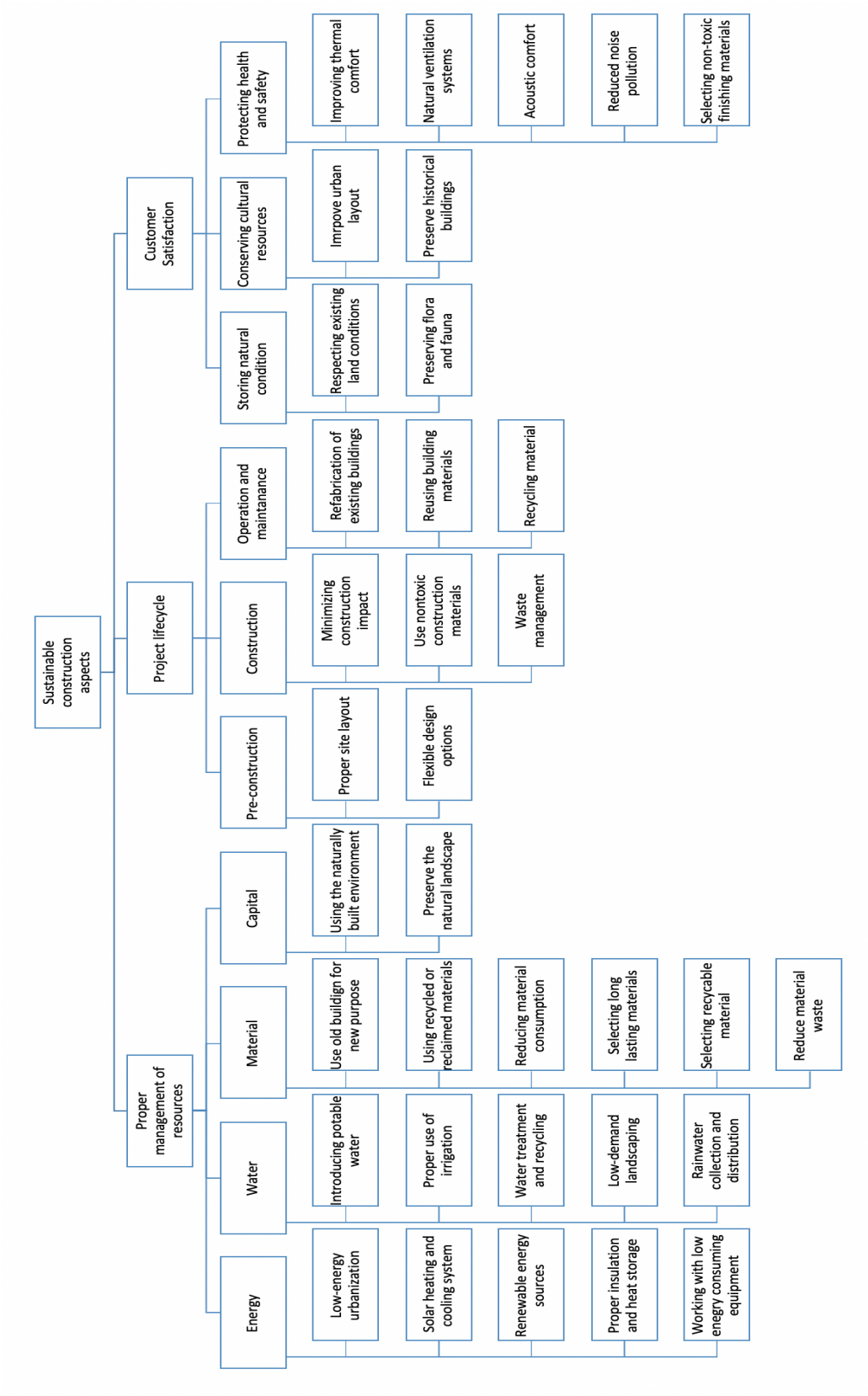

Figure 5.9 Sustainable Construction aspects

The above figure breakdown sustainable factors into three categories that will help improve sustainable construction in Lebanon. The three concepts are the proper management of resources, the project lifecycle, and customer satisfaction. These categories can be further broken down into sub-categories that identify the factors needed for improvement in order to initiate the concept of sustainable construction. However, when incurring BIM with sustainable construction, there are further aspects that need to be considered, therefore, the following analysis will expand these categories and attempt to incorporate them with the sustainability pillars of economic, social, and environmental sustainability. These categories and sub-categories will be reflected in this analysis based on their impact on the Lebanese construction economy, society, and environment. In addition, the analysis will consider the impact of BIM attributes on the sustainability pillars.

5.5.7.1 Economic Sustainability

When dealing with economic sustainability, the main target is to attempt and reduce unnecessary costs, while prolonging the life of the project with minimum impact, hence the term sustainable. Sustainable construction has been a recognized as negligible task in the Lebanese construction sector. One of the main reasons is due to lack of financial capability. However, this negligence has caused severe economic conditions as of today. Due to lack of planning and consideration, the Lebanese economy has fallen short, and construction sector has witnessed a serve financial cutback. Hence there is a need to consider an alternative more sustainable approach.

From the information gathered on BIM and its impact on the construction industry, implementing BIM will be the first step in achieving and improving the economy through sustainable construction. It is by identifying the benefits of BIM and the requirements for sustainable construction, the qualities will merge and impact the performance. The table below will demonstrate the BIM attributes and their impact on economic sustainability.

Table 5.12 BIM attributes for Economic Sustainability

BIM Attributes	Economic Sustainability Impact
Visualization	• Through 3D modelling and improved visual representation, the decision-making process becomes simpler and thus reducing uncertainties. By eliminating the risk of uncertain decisions, project will be carried out with more accurate estimations. Accurate designs lead to better executions, thus eliminating unwanted costs. • Reducing mistakes will result in lower costs of redoing the work, and these funds could be reallocated to more innovative tasks, such as designing green spaces or solar heating systems. Instead of investing money to correct errors, eliminating these errors will increase funding to consider more sustainable and long-lasting materials. • Improved visualization through BIM modelling, can aid in integrating sustainable models with long lasting material which can also lower operation costs in the future such as maintenance and refurbishment.
Analysis and Simulation	• A key benefit of BIM is running simulations and analysis that can aid in predicting future outcomes. For example, clash detection simulations help foresee upcoming errors and devise solutions or alternatives before occurrence. Thus, reducing unwanted costs and wasted material. • 4D scheduling and 5D cost estimation are another form of project simulation using BIM, using aim to reduce project durations and eliminate human errors that might cause delays and cost overruns. Eliminating errors reduce costs, and as a result increase project budgeting for more sustainable design and execution.

	• Energy analysis can facilitate sustainable design, and through that create a more sustainable execution process which will lower operation costs. In certain cases, investing a larger sum of money in present times will lead to lower costs in the future. Yet by improving design and execution through BIM, the money invested today will be through reallocated funds saved by eliminating unwanted errors in the early stages of the project lifecycle.
Information management	• BIM's single platform creates a communication line for all project participants, thus facilitating interaction and reducing misunderstands that will result in errors that will eventually require alterations. A unified platform is a method of cutting unwanted costs and creating an opportunity for further development. Improving the quality of information improves the quality of the project. • Quality is linked with sustainability, in this case, opening a line of new information which can be cost efficient and environmentally sustainable. Therefore, creating a product of higher value could be achieved with lower costs.
Project integration	• BIM could be regarded as a language, and similarly to any international financial market, there is a risk of fluctuations between project participants. However, when working under the same cloud, projects will operate smoother and easier. • Integrating BIM tools in sustainable construction aims to create a common language and a single standard between project participants. Single platforms could be achieved through single investments, which can be maintained through a single process. Common project utilities show a well-integrated system of design and execution, which can

be economical for the project with lower changes of unwanted costs, whether in project initiation or completion.

The BIM attributes are the tools can be used through the implementation of BIM in the Lebanese construction sector. These BIM tools can impact sustainable development, by improving the construction process. The focus of these tools is to eliminate unwanted costs and re-evaluate the distribution of funds for more sustainable aspects. Cutting down on errors and mistakes, while facilitating the design and execution phase, will lead to more funds in sustainable sectors, such as improved simulations and integrations.

5.5.7.2 Social Sustainability

Construction projects do not have a lot of room for testing with trials and errors, that is why every construction project is regarded as a prototype with its own unique features. A key variable that impacts the project is the society that surrounds it and works with it. This variable of society could be a positive or negative influence on the project, for that reason social sustainability has become a concern when working the confines of a construction project. As a tool BIM does not have a direct relation with social factors, yet it holds the capability to improve social sustainability and the value of the project. In Lebanon majority of construction projects are done in the capital Beirut, which is also the highest rated in noise and air pollution. The point is that random construction in Lebanon has created an uneasy living situation for the surrounding society. As a result, BIM tools can improve the sustainable construction standards if applied correctly.

Similarly, to the above section, the following table will relate BIM attributes to the social sustainability impact. The following table focuses on eliminating cultural differences and create an organized environment for the BIM implantation process by improving awareness on sustainable construction and encourage the use of technological

innovations. Customer satisfaction could be used as a method to measure social sustainability, since it focuses on delivering the best value for the society.

Table 5.13 BIM attributes for Social Sustainability

BIM Attributes	**Social Sustainability Impact**
Visualization	• Visualization has been identified as the most beneficial BIM tool, creating visual representations of the project, and aiding the decision-making process. Facilitating this process, assures director involvement and ensures better quality for the project. • Social sustainability improves the environment surrounding the project, and BIM offers an accurate site-layout, which can preserve the natural topography of the land. As a result, surroundings will not be affected negatively throughout the project lifecycle. • Moreover, through visualization, improving the site layout can increase security and safety throughout the project, making the environment more pleasant and increasing comfort.
Analysis and Simulation	• With BIM, running multiple scenario analysis has become simpler and more accurate. The fact that BIM tools can analyse detailed aspects of the construction project, offers the opportunity to redesign overlooked conditions of the project. • Eliminating noise pollution during construction and improving the overall acoustical performance are simple example of how BIM tools can provide additional comfort for the project and its surroundings. • By examining different site conditions, BIM tools can create a more efficient and sustainable atmosphere for any construction project, ensuring longer customer satisfaction.

Information management	• Information is the critical term in BIM, and for that reason the information provided throughout the project can influence the overall performance. The decision-making process does not only impact the project location and layout, it also aids in selecting less harmful material. • Effective choice of material can reduce pollution and hazards in and around the project, therefore BIM information could play a critical part when ensuring the stability of performance. • Using renewable resources will eventually reduce pollution and create a better environment for society.
Project integration	• BIM facilitates the integration of project information throughout the project lifecycle. Thus, making the work simpler and more efficient, and based on that, society finds BIM integration a key element for future projects. The ability to create a single platform for sharing information, will increase participation by all groups involved, thus creating a more pleasant work atmosphere, which eventually will result in a better outcome. • A collaborative process of work can create a long-lasting preserved environment, by simply involving all director in the project processes. Whether in the design or execution phase, constant communication between all participants, as well as the surrounding population, can result in more sustainable project.

5.5.7.3 Environmental Sustainability

With such low awareness on the importance of sustainable construction, the Lebanese construction industry has been a major contributor to many environmental issues rising in Lebanon. Environmental sustainability's aims to reduce the consumption of natural resources today, in order to provide a more environmentally friendly future. Unfortunately,

Lebanon lacks knowledge and awareness on the value and importance of sustainable construction or sustainable development in general. The issue is that Lebanon is not a naturally resource rich country, which means that they have limited resources with little flexibility and no margin for errors, otherwise the losses will be difficult to restore. The Lebanese construction sector has taken an initiative towards green building development, and as initiated the concept of sustainable construction. However, they lack the technology and capability to execute the work as expected. Therefore, BIM might be the missing component for the Lebanese construction industry to evolve and develop a more realistic suitable development plan.

Environmental sustainability has to be carried out through the entire project lifecycle. Therefore, based on the information gathered from the case studies, the project lifecycle can be divided into three parts the design, construction, and operation phase. Each phase can focus on certain aspects of environmental substantiality. Along with the appropriate BIM attribute, that are similar to economic and social sustainability, environmental sustainability can be achieved as represented in the table below. The table below shows that the design phase focus on design to achieve low energy consumption and selecting the appropriate construction material. While the construction phase focuses on minimizing carbon emissions and reducing waste generation. Finally, the operation phase highlights the importance of lowering pollution by improving on solar lighting and natural ventilation systems. BIM attributes apply throughout the project lifecycle, therefore, through the visualization and 3D modelling capability of BIM during the design phase, environmental sustainability can be improved by facilitating the decision-making process to identify the appropriate contractors and suppliers that can execute the work, based a more complex low energy consuming system. Through BIM, more advanced design can be developed to attempt and lower energy consumption for the project, in addition, the designs can specify recycled material to improve the environmental situation in Lebanon. During the construction phase, BIM models can be used to develop a proper site layout, preserving the natural land and lowering impact on the natural built environment. In addition, proper site layout, could reduce waste generation, through proper storage and expert execution.

Table 5.14 BIM attributes for Environmental Sustainability

	Project Life-cycle					
	Design		Construction		Operation	
Green Attributes	**Low energy**	**Construction Material**	**Carbon emission**	**Waste generation**	**Solar Lighting**	**Ventilation**
BIM Attributes						
Visualization	Advanced design tools for with visual specs for daylight adjustment and reduced energy consumption systems	Facilitate the decision-making process and provide multiple suppliers with recyclable and non-toxic material	Proper site layout to lower for the efficient use of equipment.	Accurate site layout for proper storage of equipment and material to minimize loses	Benefiting from daylight adjustment to store heat and reduce energy consumption and improve thermal comfort	Creating designs to incorporate natural ventilation systems
Analysis and Simulation	Energy simulation and alternative methods of achieving better value with lower consumption	Accurate estimation for construction duration to minimize impact of material on the natural landscape	4D scheduling and simulation for a day by day progress report to lower excessive consumption of energy	Clash detection simulation to avoid unexpected errors and rework leading to destroyed material and excessive waste	Multiple scenario analysis using BIM tools to preserve heat and reduce dissipation and losses	MEP simulations for efficient and sustainable operation
Information Management	Access to information by all project participants for proper utilization and alteration to fit environmental standards	Benefiting from the existing information provided by the natural built environment to avoid misuse of materials	Contractors ease of access to information and supplies to reduce equipment energy consumption	Provide accurate BOQs and quantity measurements to avoid excessive material wastes	Preserved information for future alterations and rehabilitation works that might require the use of recycled material	Support facility management and effective maintenance work for future rehabilitation works
Project Integration	Collaborative design with multiple alternative scenario and effective participation	Larger supply chain with stakeholder involvement to facilitate the decision-making process	Working with low energy consuming material and equipment to minimize air pollution	Contractor's involvement and reuse of building material	Capability for different project participants to carry out the necessary work to insure thermal comfort	Collaborative work between different project participants to provide a clear and more efficient distribution system

During the operation phase, BIM designs are more accurate and realistic, therefore, BIM can use new characteristics that were not available before, such as daylight adjustment that can store solar heating instead of consuming energy, as well as, create an accurate ventilation system.

BIM has the capability to run different analytical models with different materials during the design phase, as a result optimal performance design could be achieved before the execution of the project. Even during the construction phase, BIM's simulation can be used for the optimal performance equipment performance. BIM's capability to provide an accurate execution of the project can aid in lowering energy consumption, as well as, carbon emersions, water consumption, and waste generation. Environmental sustainability is an on-going process and therefore requires constant modification through updating the performance with constant data analysis. As a result, the operation phase can continue to perform at optimum conditions with minimal environmental impact.

Information is the key to many of the BIM attributes. The information should be shared consciously throughout the project lifecycle. As information remains accessible, modifications can made to the designs and the natural ground can be preserved. As well as, accurate estimations could provide an overall performance index during the construction phase. As consumption of resources remains limited, environmental sustainability could be developed with continuous modifications. Even during rehabilitation projects, BIM information could be easily accessible and modified to fit the new project objectives without compromising the integrity of sustainable development.

Project integration throughout the project lifecycle remain the only sustainable element within the control of the project participants. Collaborative work can lead to improved quality and overall performance. Even during the operation phase, participant collaboration could maintain sustainable performance after maintenance, as intended the original design.

5.6 Chapter Summary

This chapter introduced the companies that participated in the interview process of this research. In every company, interviews were carried out with different participants with

different backgrounds and knowledge on BIM and sustainable development. Semi-structured interviews were conducted and noted for the analysis using NVivo software for qualitative research. During the interviews seven topics were discussed and were identified as the themes for data analysis. The topics are related to BIM in the Lebanese construction industry in terms of definition, role, benefits, barriers, critical success factors, potential for change, and sustainable development. The interviews were later on developed and three case studies were presented. The case studies were used to examine the themes of BIM and using NVivo software define subthemes. BIM definition was divided into three subthemes 3D visualization, project information, and collaboration and communication. While the BIM role showed two subthemes as identified as changing the constriction management process and support sustainable construction. BIM benefits were divided based on project participants were the subthemes are the directors, project managers, designers, and contractors. The BIM barriers in the Lebanese construction industry were divided into three subthemes economic barriers, social barriers, and environmental barriers. The critical success factors presented five subthemes based on human, industry, project, process, and resources factors based on the Lebanese construction industry. BIM's potential for change showed two subthemes altering management style and supporting sustainable construction. Finally, after analysing the case studies BIM for sustainable development was divided into three subthemes economic sustainability, social sustainability, and environmental sustainably were different BIM attributes were used to analyse the impact of BIM on sustainable construction in the Lebanese construction industry.

Chapter VI: Discussion

6.1 Chapter Overview

The following chapter will compare the information gathered from the case studies and discuss the analysis with respect to the information provided in the literature review. The validity and accuracy of the gathered information from the interview process as well as the outcome of the case studies will be measured with previous research in order to compare the outcomes. This chapter will focus on BIM implementation in the Middle Eastern region and more specifically Lebanon whilst comparing the factors gathered from this research to previously determined factors. This chapter will also elaborate on the relation between BIM and sustainable construction with an emphasis on the Lebanese construction industry.

6.2 Implementation of BIM in the Lebanese Construction Industry

Building Information Modelling is a modern and innovative method of project delivery, and even though it is widely adopted in many advanced and developed countries in Lebanon it remains very primitive, and based on BIM's progressive movement, it is still very far from achieving its desirable adoption levels, as in the entire Middle Eastern region, BIM adoption levels do not exceed 25% in total (Almuntaser et al. 2018). Several researches attempted to develop a framework for implementing BIM in the construction industry by examining different BIM aspects. Almuntaser et al. (2018) examined the maturity measure of BIM in adoption and implementation in the Saudi Arabian AEC firms. Through a systematic procedure, BIM could rise from level 1 on the BIM maturity level to BIM level 2, by examining the BIM maturity measures for successful BIM implementation. The research found that limited knowledge and awareness on the benefits of BIM from the clients and owners, along with limited research, education and training have slowed down the BIM adoption process. Based on that research, it will be very insightful to attempt identifying the BIM maturity level in the Lebanese construction industry. According to Underwood and Isikdag (2010), BIM maturity is the quality in which BIM tools can be used within their capabilities, therefore they can be divided into three levels. Level 1 being object-based modelling, were the focus is on moving from 2D CAD drawing such as lines and circles, to a more component based modelling system, where objects are identified

as walls and chairs. Level 2 is a model-based collaboration, were the focus is on creating a single platform of collaboration and information exchange. Level 3 is a network-based integration system, were full collaboration can take place with an integrated web service BIM HUB.

From the information gathered in this research, interviewees discussed the importance of 3D modelling, as well as, the importance of collaborative design. However, their knowledge about BIM collaboration is theoretical and interviewees with high experience contributed to that idea. Therefore, the execution of BIM level 2 for a model-based collaboration remains a vague idea in the Lebanese construction industry. On the other hand, companies in Lebanon are moving to a more object-based modelling system, and even project participants with little experience in the industry, have identified BIM as a growing modelling tool. The lack of collaboration between project participants has restricted BIM from developing to a model-based collaboration and therefore remains far from achieving level 2 maturity. Yet, the lack of collaboration has not affected the influence of BIM on single scale companies, and the Lebanese sector has initiated a 3D modelling system. As a result, it is safe to assume that BIM is currently operating on level 1 in the Lebanese construction industry and is still at a very young level on the maturity scale.

The credibility of the information gathered in the case studies can be assessed by examining previous literature and research. Unfortunately, there is limited research available on BIM in the Lebanese construction sector. As an alternative, the information gathered from the case studies and the outcome of the analysis can be compared with neighboring countries will similar circumstances happening in the construction industry. Ahmed et al. (2018) examined the outcome of applying BIM in the Syrian construction industry, which is also in a developing country with similar economic, social, and environmental conditions. The research found that less than half of the industry is aware of BIM and its impact on the construction industry. Similar to the outcome of this research, majority of companies do not understand the impact that BIM can make on the construction sector, and as a result, education and training are very low, with the percentage of people familiar with BIM being self-taught and individually trained. The highest percentage of respondents identified that the critical barrier for BIM

implementation is the lack of clarity, which in this research showed to be a repetitive limitation on behalf of the clients and directors. The lack of knowledge and awareness have left the construction industry in confusion, and therefore underestimating the BIM capability. Finally, the research found five sets of BIM applications economic, technical, organizational, legal, and human which in comparison with the outcome of this research analysis referred to as critical success factor, which build the guide for proper implementation of BIM in the construction industry. Many similarities appear when comparing the research of Ahmed et al. (2018) and Almuntaser et al. (2018) with respect to the analysis of this research. This highlights that there is low BIM implementation in the Middle East region due to lack of knowledge and awareness that comes from limited research on the topic. According to Gerges et al. (2017), Lebanon has shown the least BIM involvement, which implies that developed countries in the Middle East such as UAE and Qatar have contributed more than developing countries such as Jordan and Lebanon. This shows that even though BIM awareness is relatively low, BIM implementation heavily depends on the financial investment of clients and directors.

Despite the benefits that came out of implementing BIM in the construction industry, the reasons to neglect this implementation process still outweigh the advantages. The reason for this lack of support for BIM is due to the complicated process of implementing BIM as well as the changes that arise for it. A research by Ullah et al. (2019), examined the benefits and barriers of BIM implementation in different countries by reviewing previous research and summarizing the outcome. The results are presented in the below tables.

Table 6.1 BIM benefits with respect to construction phase (Ullah et al. 2019)

Phases	Benefits of BIM use
Pre-construction	• Better concept and feasibility (Eastman *et al.*, 2011) • Effective site analysis to understand environmental and resource-related problems (Azhar *et al.*, 2011b) • Improve effectiveness and accuracy of existing conditions' documentation (Kjartansdottir *et al.*, 2017) • Effective design reviews leading to sustainable design (Khosrowshahi, 2017) • Enhancement of energy efficiency (Eastman *et al.*, 2011) • Resolve design clashes earlier through visualizing the model (Latiffi *et al.*, 2016) • Enables faster and more accurate cost estimation (Khosrowshahi, 2017)
Construction	• Evaluation of the construction of complex building systems to improve planning of resources and sequencing alternatives (Kjartansdottir *et al.*, 2017) • Effective management of the storage and procurement of project resources (Eastman *et al.*, 2011) • Efficient fabrication of various building components offsite using design model as the basis (Enshassi *et al.*, 2018) • BIM allows better site utilization (Deshpande and Whitman, 2014) • Reduce site congestion and improve health and safety (Khosrowshahi, 2017)
Post construction	• BIM record model can help in decision-making about operations, maintenance, repair and replacement of a facility (Kjartansdottir *et al.*, 2017) • Makes asset management faster, more accurate and with more information (Husain *et al.*, 2014) • Ability to schedule maintenance and easy access to information during maintenance (Enshassi *et al.*, 2018)

Table 6.1 shows the benefits of BIM with respect to the phase of the construction project. During the pre-construction phase, the table shows that BIM is a tool for improving the design, site layout, and accuracy, as well as, support sustainable design through energy effectivity, clash detection, and sustainable designs. While during the construction phase, BIM can prove planning of resources, prefabrication, and better utilization of site layout. Finally, during the post-construction phase BIM records can aid in maintenance and operations. In this research, the benefits were categories according to project participants, however, the BIM applications present the same benefits show in the previous table 6.1. The focus on improving design and accuracy as well as simplifying site layouts for more efficient use of resources, is the most influential BIM benefit. Based on the analysis done in this research, 3D visualization can improve any aspect of the construction process and can aid in achieving any required improved through the project lifecycle. Many other recent researches examined the benefits of BIM in the construction

industry such as Chan et al. (2019) who summarized the benefits of BIM from previous literature as seen in table 6.2.

Table 6.2 Previous literature for BIM implementation benefits (Chan et al. 2019)

Benefits of BIM Implementation	Description
1. Improve project quality	BIM implementation improve project quality variables by facilitating the ease of assessment of construction materials and work process
2. Better understanding of design	The application of n-dimension (3D) could ease the ability of the project team to visualize and understand the design by using some essential functions like "rendering" and "walk-through.
3. Provide life cycle data	The information generated by the BIM system can be utilized in the whole life cycle of the project.
4. Scope clarification	BIM is an appropriate tool to check clashes and reduce discrepancies among design drawings.
5. Speed up the design process	BIM ease the process of the project design earlier to ensure all stakeholders understand and approve the design earlier.
6. Reduce construction cost	BIM model can facilitate effective site planning to enhance efficiency as well as reduce the rework to save time and money
7. Better cost estimates and control	BIM can generate some data including the quantities of materials automatically which can increase the accuracy of the cost estimate and control compared to the manual measurement
8. Better construction planning and monitoring	BIM system can display a very clear full picture of the project and show the work sequences on a computer before the actual commencement of the project on-site
9. More efficient communications	The BIM system facilitates and eases the process of knowledge-sharing and coordination in the industry.
10. Reduce project duration	BIM facilitates the delivery of a construction project on or before schedule.
11. Improve safety performance	BIM system facilitates the integration of safety precaution and variables which can be simulated to improve safety on site.
12. Enhance organizational image	An organization policy or strategy toward integrating and implementing BIM in their work processes can improve their competitive advantage.

Looking at the previous literature and comparing the benefits of BIM with the ones presented in this research, an assessment can be derived based on the BIM implementation phase and the benefits of BIM. As a result, the benefits presented are theoretical references for the pre-implementation phase of BIM.

Several barriers and limitation have been hindering the successful implementation of BIM, and therefore, these benefits are based on experience and knowledge of BIM so far. Unfortunately, BIM implementation is not fully optimal which limits the expected benefits. As BIM integration in construction projects becomes clearer and more perceivable, more benefits are expected to arise. As a result, BIM benefits have reached a saturation point, as of today, due to the barriers and restrictions preventing the evolution of BIM further in the construction industry. The benefits of BIM presented in tables 6.1 and 6.2 are based on previous literature and studies carried out to understand BIM's potential. The analysis in this research found that there are limited knowledge and experience with BIM in the Lebanese construction industry, and as a result the expected benefits are based on previous on the understanding of BIM from previous literature. Until BIM becomes a fully adopted in the Lebanese construction industry, identifying future benefits requires an

evolutionary transition from BIM's current state to a higher one, or in other words, a level 2 implementation of BIM on the BIM maturity scale.

Attempting to identify the barriers and limitation is a key method to transition from BIM level 1 to BIM level 2. Current research shows that there are many barriers restricting BIM adoption in the construction industries. A research by Ullah et al. (2019) reviewed previous literature and identified the factors presented in table 6.3 as barriers limiting BIM adoption.

Table 6.3 Previous literature for BIM implementation barriers (Ullah et al. 2019)

Barriers	Reference
High initial cost	(Ismail *et al.*, 2017)
Lack of awareness about BIM benefits	(Latiffi *et al.*, 2016), (Gerges *et al.*, 2017)
Inadequate training on the use of BIM	(Eadie *et al.*, 2014) (Park and Kim, 2017)
Resistance to change current construction industry culture	(Ganah and John, 2015) (Sahil, 2016)
Insufficient governmental support	(Enshassi *et al.*, 2016)
Legal issues	(Bosch-Sijtsema *et al.*, 2017)
Lack of interest from clients	(Sahil, 2016)
Lack of support from top management	(Ganah and John, 2015)
Doubts about ROI	(Eadie *et al.*, 2014)
Lack of BIM experts	(McAuley *et al.*, 2017)
Data ownership issues	(Park and Kim, 2017)
Longer process (takes longer time to develop the model)	(Ismail *et al.*, 2017)
Lack of demand from the contractors	(Gerges *et al.*, 2017)
Sub-contractors are not interested in using BIM	(Hosseini *et al.*, 2016)
Absence of contractual requirement for BIM implementation	(Ahmed *et al.*, 2014)
Complexity of the BIM model	(Ahmed *et al.*, 2014)
Interoperability between software programs	(Park and Kim, 2017)
Lack of standardized tools and protocols	(McAuley *et al.*, 2017)

The analysis carried out in this research divided BIM barriers into 3 categories, economic, social, and environmental. The information gathered in previous research and shown in table 6.3 are a subset of these categories such as the high initial cost, reluctance to change, and lack of standardization. Table 6.3 along with the information gathered in this research shows that at the early stage of BIM implementation, the barriers that restrict its adoption are similar in any construction industry. Developing countries such as Lebanon, adopt new technology and innovation based on their success in more developed countries. Unfortunately, the Lebanese construction industry is facing external limitation that are not industry related but related to the country itself. Low demand on BIM in construction project, as well as, the low-income salaries for employees due to the bad

Lebanese economy, have further extended the BIM implementation process. As a solution, a recent study by Olawumi and Chan (2019) developed a benchmarking model for BIM implementation in developing countries. The purpose of this research is to examine developed countries and set a benchmarking model to be used in developing countries.

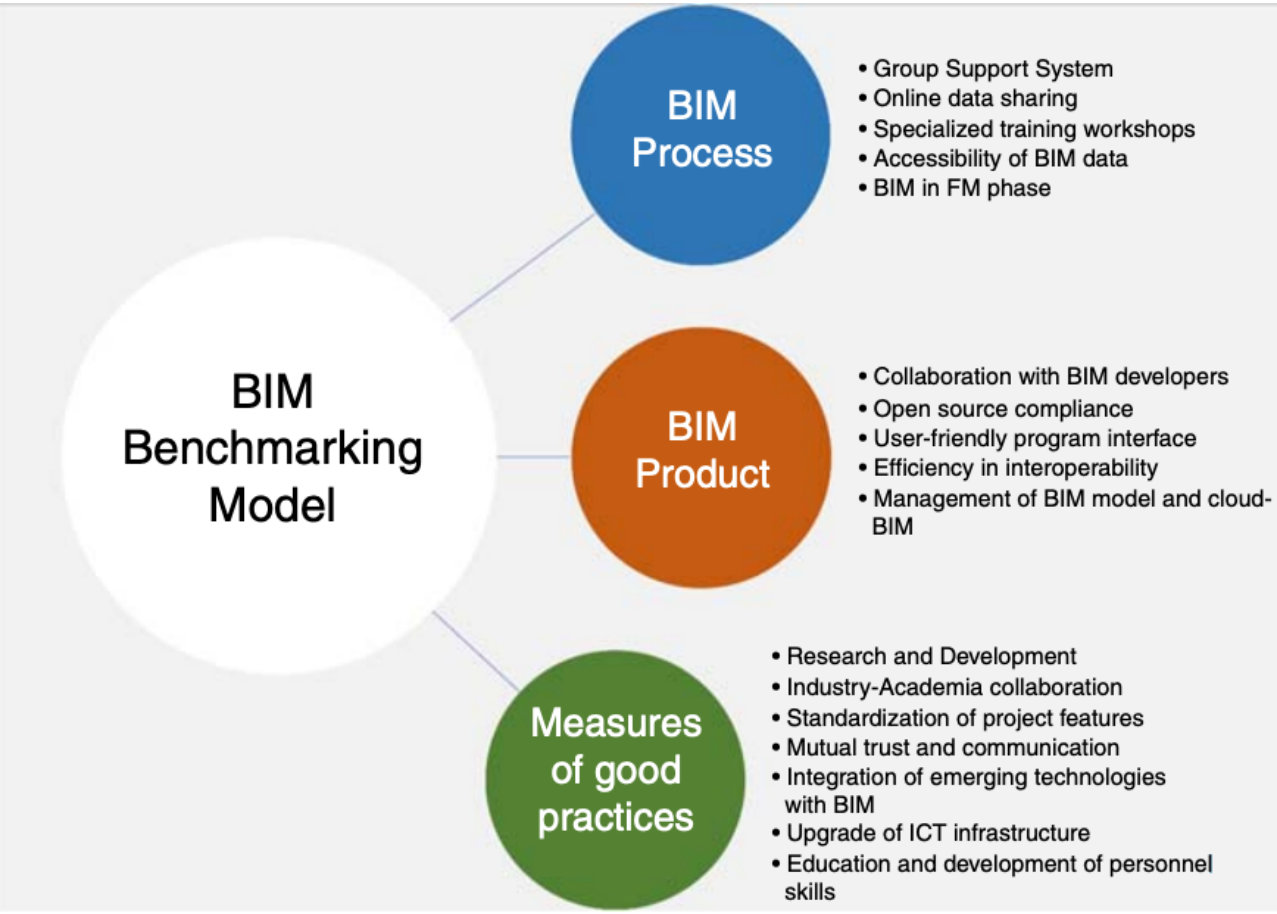

Figure 6.1 Benchmarking model for BIM implementation on developing countries (Olawumi and Chan 2019)

Figure 6.1 identifies the scoring criteria that can be used as a method of identifying the level BIM implementation existing in current performance. These criteria were extracted from examining developed countries and there use of BIM technology. The Benchmarking Model can be used to score system to understand the current BIM performance in developing countries. In the conclusion, Olawumi and Chan (2019) found that BIM in developing countries is still very young and in its earliest stages. As a result, overcoming the barriers for BIM implementation is a long and time-consuming process, which requires

a large commitment from construction companies to reevaluate the sector while considering the process and product factors of BIM.

A relevant starting point to consider for implementing BIM in the Lebanese construction sector are CSFs. Recent research studies by Olawumi and Chan (2019), as well as, Antwi-Afari et al. (2018) and Amuda-Yusuf (2018) investigated Critical Success Factors for the implementation of BIM in the construction industry. The outcome shows several factors that can impact the adoption of BIM, similarly to the factors identified in this research. The table below shows several CSFs that are extracted from previous literature and considered as the drivers for the successful BIM implementation initiation process.

Table 6.4 Previous literature for BIM implementation CSFs (Antwi-Afari et al. 2018)

Item	CSFs
1.	Earlier and accurate 3D visualisation of design
2.	Enhancing exchange of information and knowledge management
3.	Collaboration of simultaneous access of construction work
4.	Better design/multi-dimensional design alternatives/applications
5.	Design coordination on various elements/components
6.	Predictive analysis of performance (energy analysis, e.g. CO_2)
7.	Thermal energy analysis and simulation
8.	MEP analysis and simulation (HVAC)
9.	Structural analysis and design
10.	Predicting environmental analysis and simulation (airflow, weather)
11.	Acoustical analysis and simulation (sound)
12.	Verification of consistency to the design intent
13.	Ensuring effective communication among project participants
14.	Collaboration in design, construction, engineering and facility management stakeholders
15.	Providing BIM models for shop drawings
16.	Providing BIM models for offsite prefabrication
17.	Providing better implementation of lean construction, green sustainability and integrated project delivery
18.	Reducing construction project duration
19.	Reducing construction project cost
20.	Model checking and validation (reviewing code)
21.	Improved construction project performance and quality
22.	Accuracy and reliability of data (less reworking and fewer document errors and omissions)
23.	Improved site layout, planning and site safety
24.	Reduced claims or litigation (risks)
25.	Improved operations and maintenance (facility management)
26.	4D construction scheduling and sequencing (3D + time)
27.	5D cost estimation and scheduling (3D + time + cost)
28.	Coordination and planning of construction works
29.	Integrating project documentation/bid preparation
30.	Synchronization of procurement with design and construction
31.	Integrating design validation (clash detection)
32.	Extracting cost estimation and quantity take off
33.	Remodeling and renovation
34.	Photorealistic rendering for marketing purposes

The point of identifying the driver and CSFs of BIM implementation is to prioritize their impact on the construction sector. By developing a priority system, the construction industry can focus on the divers of most significance. From previous literature, the most significant factors are related to knowledge and awareness, as can be seen in table 6.5.

Table 6.5 Previous literature for ranking CSFs (Olawumi and Chan 2019)

Factors	Ranking	Significance	Agreement level
Number of subcontractors experienced with BIM projects	1	Very important	Very strong
Greater awareness and experience level within the firm	2	Very important	Strong
Increased involvement of project stakeholders in green projects	3	Very important	Strong
Clarity in requirements and measures for achieving sustainable projects	4	Very important	Strong
Interoperability and data compatibility	5	Very important	Strong
Availability and a well-managed in-house database of information on similar projects	6	Very important	Strong
Effective collaboration and coordination among project participants	7	Very important	Strong
Supportive organizational culture and effective leadership	8	Very important	Strong
Establishment of a model of good practice for BIM and sustainability implementation	9	Very important	Strong
Adequate construction cost allocated to BIM	10	Very important	Strong
Information and knowledge sharing within the industry	11	Very important	Strong
Development of appropriate legal framework for BIM use and deployment in projects	12	Very important	Strong
Shared risks, liability, and rewards among project stakeholders	13	Very important	Strong
Client satisfaction level on BIM projects	14	Very important	Strong
Project complexity (regarding building shape or building systems)	15	Very important	Strong
Availability and affordability of cloud-based technology	16	Very important	Strong
Early involvement of project teams	17	Very important	Moderate
More training programs for cross-field specialists in BIM and sustainability	18	Very important	Moderate
Technical competence of staff	19	Very important	Moderate
Increased research in the industry and academia	20	Very important	Moderate
Government establishment of start-up funding for construction firms to kick-start BIM initiatives	21	Very important	Moderate
Security of intellectual property and rights	22	Very important	Moderate
Establishment of BIM standards, codes, rules, and regulations	23	Very important	Moderate
Appropriate legislation and governmental enforcement and credit for innovative performance	24	Very important	Moderate
Client requirement and ownership	25	Very important	Moderate
Standardization and simplicity of BIM and sustainability assessment software	26	Very important	Weak
Technical support from software vendors	27	Very important	Weak
Availability of BIM and sustainability databases	28	Very important	Weak
Open-source software development	29	Very important	Weak
Availability of financial resources for BIM software, licenses, and its regular upgrades	30	Important	Lack

Knowledge, awareness, and experience are the building blocks for any process; therefore, BIM requires an impactful set of skills and attributes to be executed successfully. Before introducing the software and the models, BIM requires knowledge and a strategic plan of execution, hence, the purpose of prioritization. By identifying the variables that have the most impact and begin the initiation process from that level, BIM could be introduced in the construction sector, and CSFs can be used as a guide to improve the process of integration.

The process is not simple, especially in the Lebanese construction industry, due to the limited appreciation for innovation and technology. BIM, in its early stages, requires careful planning and a proper implementation strategy, which project participants find irrelevant and unnecessary due to the limited demand on BIM projects. Any improvement in the construction sector, could benefit the whole Lebanese economy, there a framework for successful BIM implementation is required. The information gathered from the case studies carried out in this research, serve as a guide for developing the framework of BIM implementation in the Lebanese construction industry. A framework for BIM implementation has not been properly developed, especially for developing countries. Knowing that BIM could have a potentially significant impact on sustainable construction, the following section will use the information gathered throughout this research on sustainable construction in Lebanon, as well as, examine previous literature on BIM and sustainable development, in order to develop a framework for BIM implementation and understand the impact on sustainable construction. The purpose of understanding the relation between BIM and sustainable development from previous studies, is to develop the link between BIM and sustainability that can be achieved through a successful implementation strategy from BIM in the Lebanese construction industry.

6.3 Achieving Sustainable Development through BIM Implementation

The relation between BIM and sustainable development was first addressed by Krygiel and Nies (2008), were the concept of Green BIM was first examined, aiming to achieve sustainable development using BIM. It was first indicated that BIM could aid sustainable development by improving issues such as building orientation, building form and envelope, daylight analysis, water harvesting, energy modelling, sustainable material, site

and logistics management. Wong and Zhou (2015) carried the research of Green BIM, were by examining different case studies along with various publication and previous research, concluded that the Green BIM initiative have been gaining significant attention, yet lacks the necessary organizational skills and management tools to carry on.

The concept of Green BIM is still being examined, and recent research by Mohammed (2019) aimed to achieve a sustainable BIM model to manage the relation between BIM and sustainable development, due to the lack of an integrated model to activate sustainable construction. The research found three performance indicators to manage and assess sustainability during a project lifecycle, economic, social, and environmental performance measures. The criteria used by Mohammed (2019) is similar to the ones addressed in this research. The figure below demonstrates the aim of each performance measure.

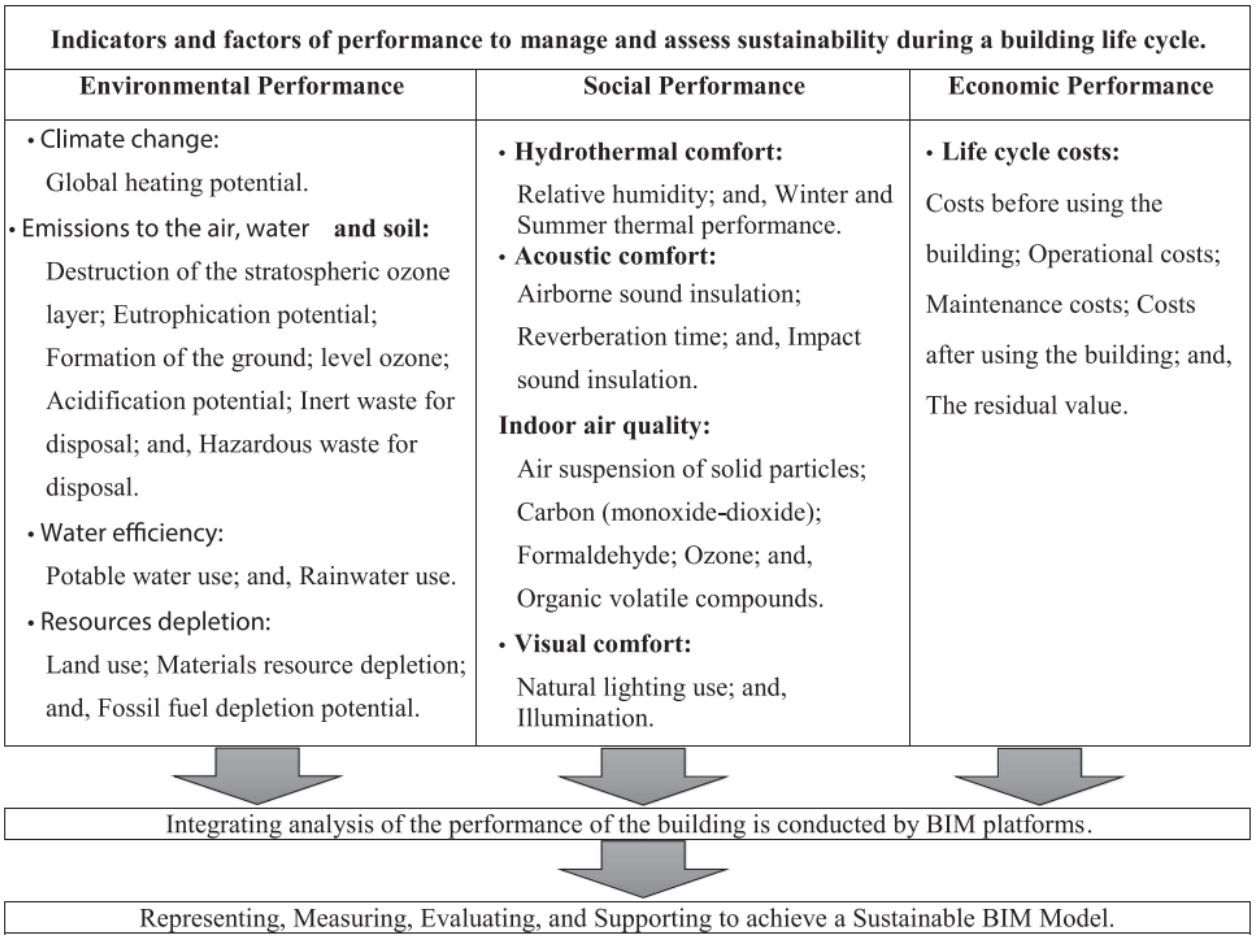

Figure 6.2 Sustainability factors for integrating BIM platforms (Mohammed 2019)

The research done by Mohammed (2019) shows that there are three main performance measures for sustainability, similarly to the outcome of the analysis done in this research, sustainability can be measured from economic, social, and environmental factors. The purpose of this classification is to identify how BIM integration can facilitate sustainable development on a micro scale. From economic perspectives, sustainable development can be achieved by lowering the initial costs of the building as well as the operation and maintenance costs. Looking at the analysis chapter section 5.5.7.1, which highlighted he BIM attributes that can aid in achieving economic sustainability.

Section 5.5.7.2 discussed the BIM attributes that can aid in achieving social sustainability, which according to the above figure, emphasizes increasing comfort. Whether HVAC, acoustic, indoor air quality, or visual comfort, the purpose of achieving social sustainability is to improve the general quality of the living situation. Section 5.5.7.3 which focusses on environmental sustainability examined similar aspects to the above figure which highlighted the importance of carbon emissions, water consumption, natural resources consumption, and proper land use.

The purpose of categorizing sustainable performance indicators is understand the proper areas where BIM could provide the most beneficial impact. The aim is to reduce cost, while improving the quality of leaving with fewer resources, which has shown to be a difficult task to achieve especially with developing countries such as Lebanon. The Lebanese construction sector has shown little value towards sustainable development, the main reason is due to lack of technological developments that can aid in achieving such high-quality standards. On that basis, categorizing sustainable performance measures can aid in adopting BIM tools in the correct format. BIM is not the only tool that has been used to achieve sustainable development. A research by Wang et al. (2019), utilized BIM and Geographical Information Systems (GIS), which is another form of information and communication technology (ICT), to improve sustainable performance throughout the project lifecycle. The focus on previous research and the co-occurrence analysis for term relating BIM, GIS, and sustainable development showed that increasing number of technological advancements adopted in the construction sector, has shown significant improvements on the sustainable performance of construction project.

In other words, adopting technology such as BIM and GIS will aid in achieving better sustainable outcomes, from an economic, social, and environmental performance measure. Nevertheless, research has shown that this topic requires further development, as many limitation and barriers still hold the growth of sustainable construction as well as the barriers that limit the adoption of BIM in the construction industry. Ahuja et al. (2018) aimed to identify the technical skills along with social skills that can be adopted by employees to improve their BIM skills to deliver sustainable and lean construction. The research shows that BIM implementation is based on two major capabilities organizational and individual, which can be later broken down into technical and social, as represented in the following figure.

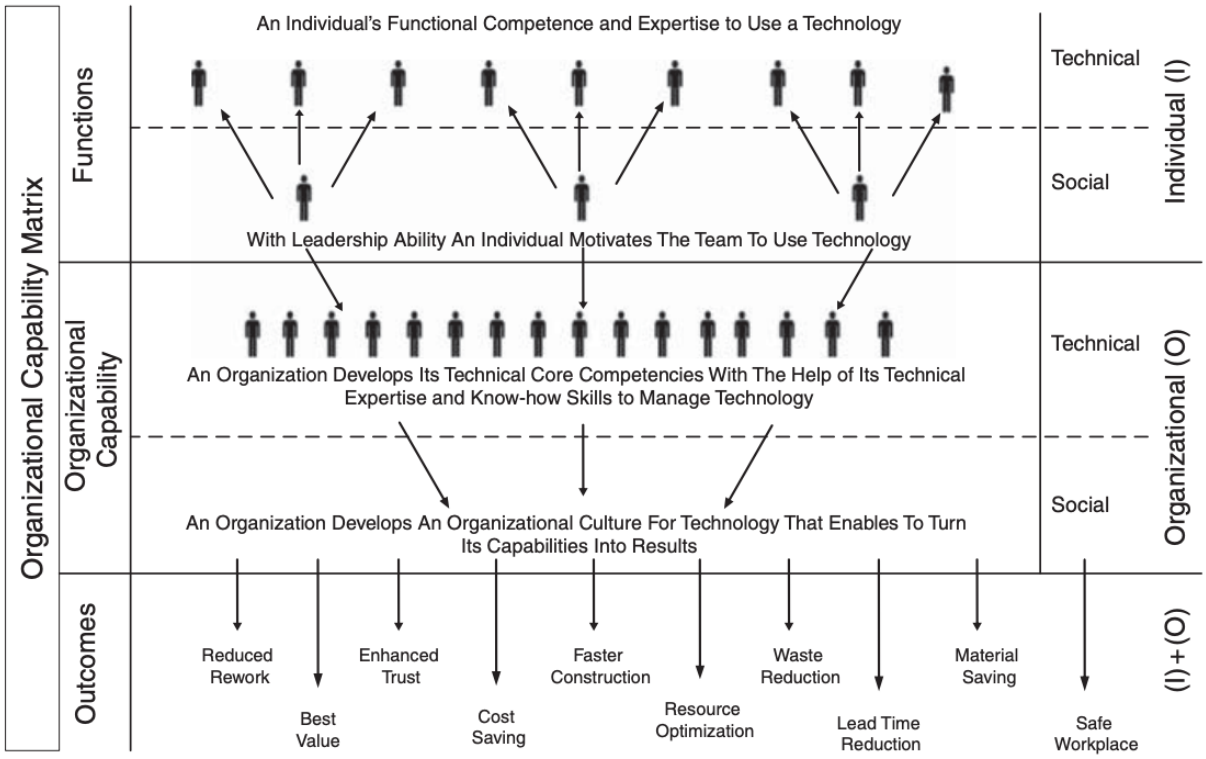

Figure 6.3 Organizational Capability Matrix (Ahuja et al. 2018)

The outcome of the research shows that in order for an organization to achieve sustainable growth, individual targets must be set by the organization itself to encourage employees to develop their BIM skills to achieve a lean and sustainable outcome. The point is that one entity with the other cannot achieve the desired outcome. Examining the case studies presented in this research, the analysis shows that the organizational entity

in the Lebanese construction sector lacks support from the government. Private project does not conduct sustainable project due to the lack of demand from project owners, while public projects do not support sustainable construction due to lack of demand from the government itself. Before improving individual and organizational capabilities, there should be a governmental support from standards and regulations that set the stage for BIM adoption and focus on sustainable construction. The lack of government support removes the pressure of companies to invest and consider sustainability as part of the project development. This has led to lack of development in the Lebanese construction sector lowering the necessity for research and development, and as a result decreasing the rates of awareness and knowledge in the construction sector.

6.4 The Green BIM Initiative

As part of countering the effect of low awareness levels and lack of regulations and legislations that limit BIM and sustainable construction, the Green BIM initiative came into play as a way to shed light on the impact of BIM on sustainable construction, and the tools that BIM provide to improve sustainable development. Ismail et al. (2019) reviewed previous research related to green building development and its relationship with BIM. As part of the finding, Green BIM has been a growing topic which joins the BIM tools and practises with Green designs. Green building development is part of sustainable development, where BIM tools are used to run simulation to lower the impact of that construction project on the environment as well as its impact on socio-economic factors. The study shows that several researches related to sustainable development have addressed green building development with the aid of BIM.

In Lebanon green building certification such as the LEED have taken on the green initiative to improve sustainable development. However, the BIM factors is currently missing, due to low understanding between BIM and green building development which will eventually result in a sustainability movement. Ebrahim and Wayyal (2019) further examined the relationship between BIM and sustainable development. The tools provided by BIM, which are addressed in this research as BIM benefits in section 5.5.3, can provide result capable of changing the traditional construction process to a new innovative green one known as Green BIM. Due to Lebanon's low BIM maturity level, the Green BIM

initiative could not be achieved as of today. However, as mentioned in previous sections, sustainability can be considered in three categories, social, economic, and environmental. Green BIM focuses on the use of BIM tools to achieve better environmental sustainability. Yet, considering BIM for sustainability improvement cam be initiated on socio-economic factors which will eventually pick up the Green BIM initiative, thus the focus on improving environmental conditions requires an organisational change and an individual development process (Ahuja et al. 2018).

6.5 Chapter Summary

This chapter compared previously examined research on BIM and sustainable development with the output that resulted from this research. Due to the low levels of research and knowledge of BIM in Lebanon, countries with similar circumstances were used to provide literature on the BIM topics. This chapter showed that the BIM barriers, CSFs, and sustainable outcomes presented in this research are the basis of using BIM tools to achieve sustainable construction. This chapter also presented the concept of Green BIM, a topic of increasing interest and the potential future of sustainable construction.

Chapter VII: Theoretical Framework and Validation

7.1 Chapter Overview

The following chapter will introduce the theoretical framework developed throughout this research. After conducting a thorough analysis from the information gathered from the case studies, as well as, comparing this information with previous studies and literature, this chapter will assemble all the gathered information to develop a theoretical framework for the successful implementation of BIM in the Lebanese construction industry. Furthermore, this framework will be tested and validated by participating companies, who have recently taken on the task of adopting BIM as part of their company development. This chapter will test the accuracy and precision of the developed theoretical framework, after careful examination of previously executed frameworks, which might be lacking necessary components to deliver the expected outcome.

7.2 BIM Theoretical Framework

The aim of this research is to develop a theoretical framework for the successful implementation of BIM in the Lebanese construction industry whilst validating the accuracy of this framework from sustainable perspectives. In order to properly develop a framework, a qualitative research was conducted, in which interviews with Lebanese construction companies were carried out to identify the barriers limiting BIM implementation and to understand the BIM attributes needed and are necessary to achieve sustainable development. These objectives were set as a milestone to help in developing the BIM framework.

7.2.1 Rationality of Proposed Framework

The limited BIM implementation in developing countries, motivated several researchers to investigate the reasons behind the lack of a successful BIM implementation strategy in the construction industry. Furthermore, the global realization on the importance of sustainable development and its relationship with the construction sector, has pushed for the development of new construction methods that preserve the environment and minimize the impact on the economy and society. Previous research such as Wang et al. (2019) emphasized the importance of adopting new technologies in order to improve the overall performance of the construction sector and deliver more sustainable projects.

Frameworks developed by Mohammed (2019) and Dave et al. (2018) attempted to integrate BIM with other forms of technological advancements, such as geographical information systems (GIS) and Internet of Things (IoT) respectively, in an attempt to develop an implementation strategy for BIM in the construction sector and understand its impact on sustainable construction. Nevertheless, there is still a gap in understanding the aspects of BIM that are linked to sustainable performance. As a result, this research was carried out with an inductive approach, in an attempt to establish and theorize the BIM attributes responsible for achieving economic, social, and environmental sustainability developments.

From the information gathered throughout this research, in order to properly develop a successful BIM implementation strategy in the Lebanese construction sector, there are three components that need to be analyzed. The first components are the barriers that are limiting the implementation of BIM in the Lebanese construction sector today. From the analysis, these barriers were divided into economic, social, and environmental barriers, where each barrier exemplifies the issues that are holding the Lebanese construction industry from adopting BIM as part a construction project. The reason for exploring the barriers, is to understand why BIM is being overlooked as a tool in the Lebanese construction sector. Once the problem is identifying, solution can be developed accordingly, hence the need to understand these barriers.

The second component to consider for developing a framework for the successful BIM implementation is BIM itself. Understanding the barriers helps consider why BIM implementation is relatively low in the Lebanese construction sector, while understanding BIM helps establish how BIM implementation could change the Lebanese construction industry. BIM tools are still new and vague for construction companies in Lebanon, and it is important to establish a border for BIM maturity in today's market. Understanding BIM maturity levels, aids in understating the current BIM level in the sector (Almuntaser et al. 2018). As a result, an analysis had to be carried out in order to understand the perspective of construction companies towards BIM and their belief of how BIM could change the construction industry. However, to develop a framework of BIM implementation, BIM attributes, as well as CSF, had to be examined and established in order to acquire the

necessary BIM tools and attributes that will eventually aid in achieving sustainable development.

The third and final component that requires careful examination in order to proceed with developing a BIM framework is sustainable development. The analysis shows that sustainable development can be measured by the sustainability pillars of economic, social, and environmental factors. The division of the sustainability pillars is the identification of what the framework intends to achieve. The barriers represent why it is necessary to consider the framework, the BIM tools answer the question of how BIM could solve the problem, and finally the sustainable outcome shows what these BIM tools aided in achieving.

7.2.2 Theoretical Framework for BIM Implementation and Sustainable Development

Underlining the components necessary to implement BIM in the Lebanese construction sector, provide a clear path for adopting a strategy of BIM implementation. The roadmap created by these components, pave the way for a step-by-step execution plan for BIM implementation whilst evaluating its impact on sustainable performance.

7.2.2.1 Economic Barriers Component

The barriers represent the first component of the BIM framework. These barriers where divided into three categories economic, social, and environmental. From the information gathered throughout this research, economic barriers are the financial factors that are limiting BIM implementation in the Lebanese construction, such as:

- Lack of investment in technological advancements
- High initial cost for starting up with BIM
- Uncertainty and High risk when working in the low levels of BIM
- High training cost for new employees
- High employee salaries for worker familiar with BIM
- Low growth rate for the Lebanese construction sector
- Open transparency for contractors and project participants
- Low director involvement especially with company directors

7.2.2.2 Social Barriers Component

Social barriers are the limitations resulting from people's perspective and acceptance of BIM in the construction sector. These barriers are:

- Reluctance to change and adopt new technology
- Lack of knowledge and awareness on BIM use
- Long learning process which employees do not have the patience for
- Low working force due to unfamiliarity with BIM tools
- Not included in the university curriculum thus the lack of knowledge
- Limited research shows lack of interest or development
- Lack of experience and skill does not push for BIM adoption

7.2.2.3 Environmental Barriers Component

Environmental barriers are the limitations resulting from the lack of interest in sustainable and green construction. Barriers such as:

- Low awareness levels on the importance of sustainable development
- Lack of frameworks integrating BIM and sustainable development
- Limited environmental parameters to work within
- Lack of sustainable development tools
- Lack of standardization and regulation
- Lack of Green BIM and use of technology for Green construction

7.2.2.4 BIM Tools Component

Nevertheless, introducing BIM in the Lebanese construction industry will introduce new tools and capabilities to mitigate these barriers and open new opportunities to manage construction projects differently. Tools such as:

- Visualization
- Design coordination
- Facility Management
- Integrated Site Layout
- Scheduling and Cost estimations

- Information Management
- Coordination and Collaboration
- Energy Analysis
- MEP System Modelling

7.2.2.5 Economic Sustainability Component

Once these tools have been fully integrated in a construction project, the outcome will result in an improved sustainable project. Sustainability will be categorized based on the sustainability pillars. From economical perspective BIM will result in:

- Reduce rework levels
- Aid in selecting economical material
- Facilitate refurbishment projects
- Facilitate the decision-making process
- Reduce construction time
- Reduce cost of errors
- Clash detections
- Lower Operation cost

7.2.2.6 Social Sustainability Component

From a social perspective, social sustainability will improve by:

- Improving worker productivity
- Improving health and safety
- Improving visual aesthetics
- Facilitate access of information
- Enhance trust between project participants
- Facilitate participation and involvement
- Improve thermal comfort
- Improve surrounding environment and persevere the land

7.2.2.7 Environmental Sustainability Component

Environmental sustainability will be achieved through:

- Selecting sustainable construction material
- Improving HVAC system
- Improved solar lighting
- Reuse of construction material
- Lowering energy consumption
- Reduce air pollution
- Reduce waste generation
- Reduce noise pollution
- Reduce water consumption

Combining the barriers that limit BIM implementation with the appropriate BIM tools, will result in the desired outcome. As a result, the following figure shows economic, social, and environmental barriers that have been introduced to BIM tools.

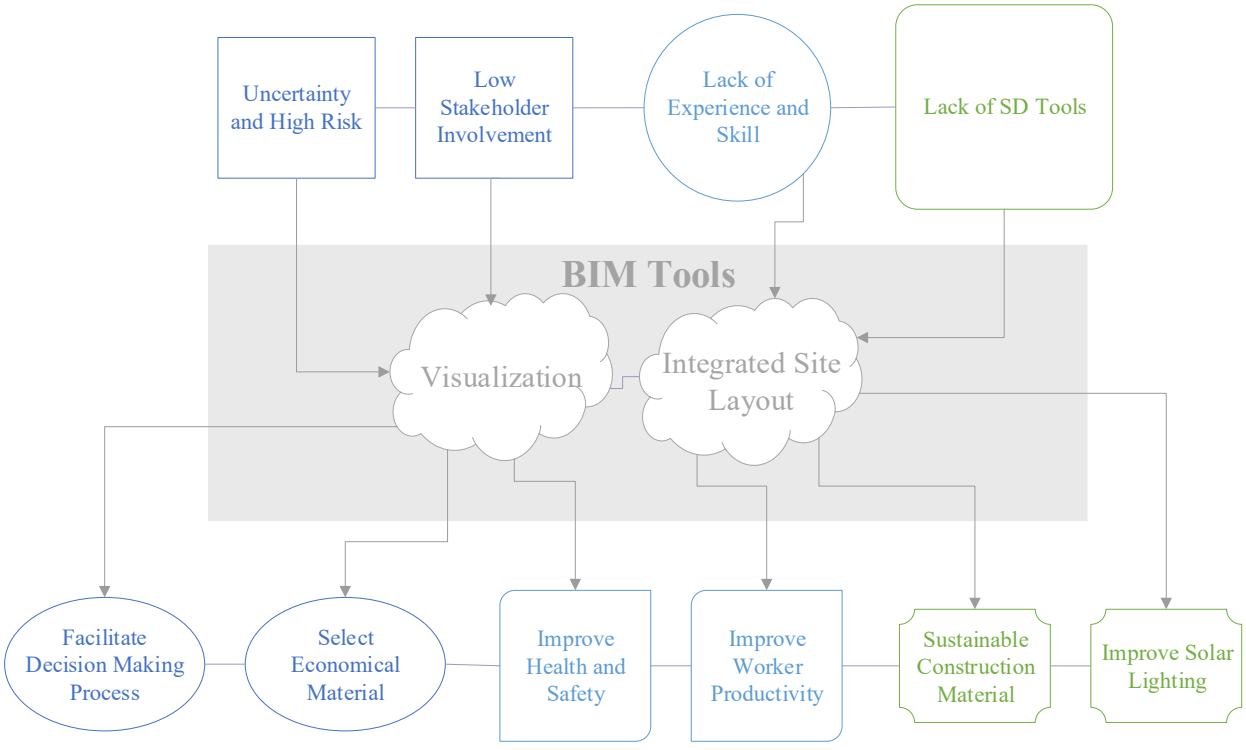

Figure 7.1 Function of proposed framework

Based on the figure uncertainty and high risk, along with low director involvement are examples of economic barriers, while lack of experience and skill is an example of a social barrier, while lack of sustainable development tools is an example of environmental barriers. Combining these barriers with the appropriate BIM tools will create an alternative sustainable outcome. Visualization and integrated site layout are an example of BIM attributes that can produce a more sustainable result for the project. Once these barriers have been incorporated with BIM tools, the excepted outcome will show an easier decision-making process and thus more economic selection of construction material. As a result, this will be an advancement in economic sustainability. While improving health and safety along with improving worker productivity are an example of social sustainability development, and finally improving environmental sustainability by selecting sustainable construction material, reuse of recycled material, and improving solar lighting.

The above figure is an example of specific economic, social, and environmental barriers that have been integrated with some BIM tools to generate a developed sustainable outcome from economic, social, and environmental perspective.

Combining all seven layers of economic, social, environmental barriers with the relevant BIM tools that will result in economic, social, and environmental sustainability with generate the desired framework as a guide for BIM implementation in the Lebanese construction sector as shown in the following figure.

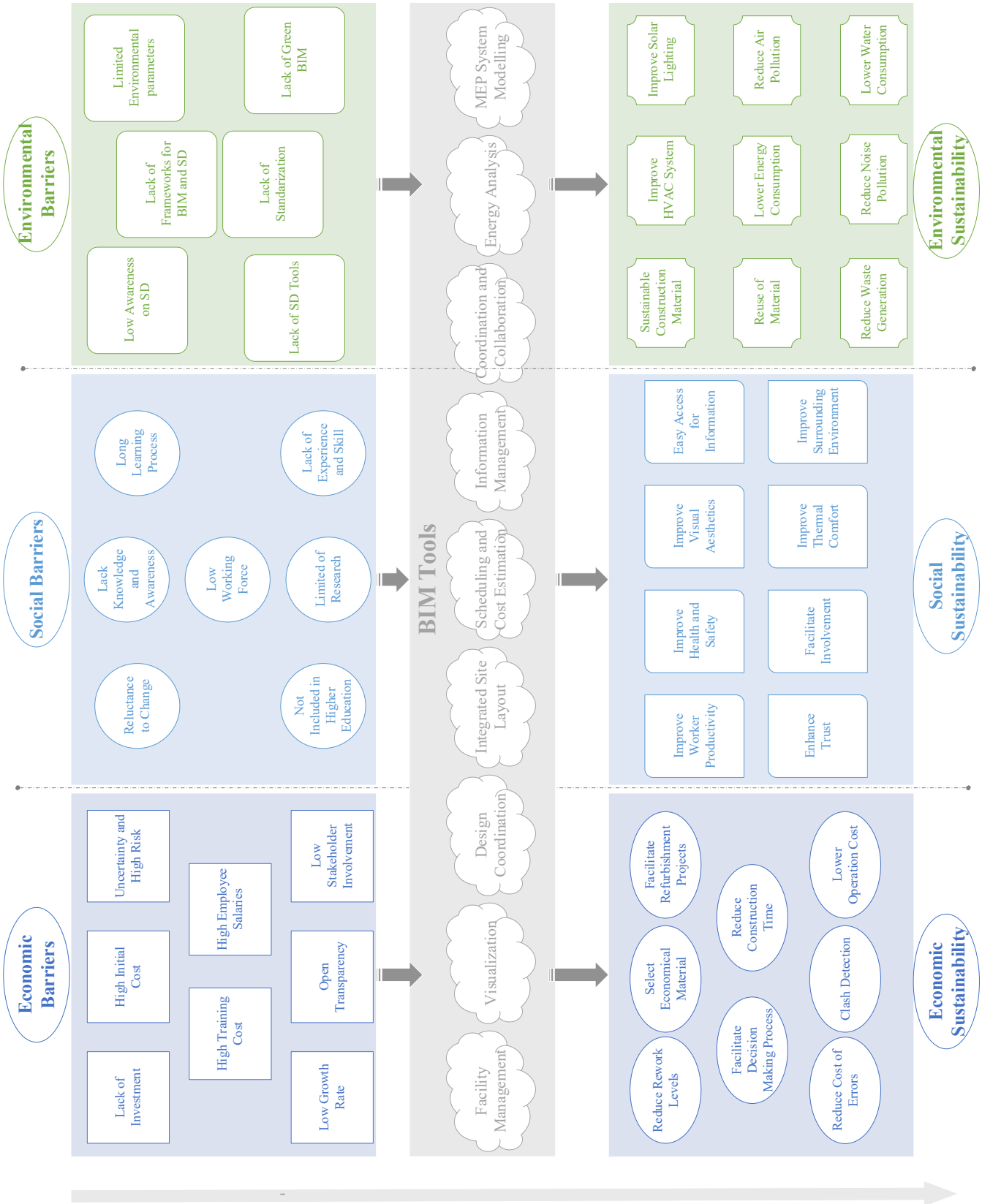

Figure 7.2 Proposed theoretical framework for BIM implementation for sustainable construction

The above figure is a representation the theoretical framework developed by analyzing the barriers that limit BIM implementation in the Lebanese construction sector, and identifying the BIM tools and attributes that can aid in overcoming and reducing the impact of these barriers, as shown in the figure this is referred to as the pre-implementation phase of the timeline. With the proper tools working to reduce the impact of these barriers, sustainable development can be achieving by incorporating these BIM attributes in the construction industry and focus on using them for the benefit of economic, social, and environmental sustainability. As a result, adopting this framework will aid sustainable development in the Lebanese construction industry by introducing BIM as a tool capable of doing so.

7.3 Validation of the Theoretical Framework

The validation of the framework shows the accuracy of the acquired results from participants in the industry. Therefore, in order to estimate the validity of this framework, two companies were asked to examine the components of this framework and provide a feedback on their opinion for this BIM implementation framework. The validation process was conducted through interviews, were four participants from every company shared their opinion on the validity and reliability of the proposed framework. The tables below introduce the interviewees that participated in the validation interview.

7.3.1 Participants for the Framework Validation Interviews

The first four participants also took part in the data collection interviews from company CC. The purpose for submitting the proposed framework for CC is to examine the accuracy of the data analysis process from the information gathered in the data collection process. CC, a company familiar with this research and significantly contributed to the outcome, examined the proposed framework in order to provide a feedback based on their knowledge and experience of the current state of BIM in the Lebanese construction industry today. The following table presents the participants role and the purpose of interviewing this participant.

Table 7.1 CC participants for framework validation

Interviewee	Role	Aim
CC1	Director	Estimate the feasibility and workability of the proposed framework
CC2	Head of Research and Development	Establish the BIM maturity level and its relationship with sustainable development
CC3	Department Manager	Examine all components of the proposed framework and their compliance within company regulations
CC4	Project Manager	Estimate the accuracy of the framework and the impact of the components on sustainable development

The following company is a new company who did not participate in the data collection interviews. The reason for involving this company for the validation process is due to the prospective adoption of BIM in the company. At the moment this company, which will be referred to as company D (CD), has not yet introduced BIM in their construction process, however, they have recently decided on adopting BIM, thus the reason proposing the developed theoretical framework as a guide for the implementation process. The table below introduces the interviewees and the aim of the interview. The participants and the aims are the same as company CC, for the purpose of insuring an accurate and homogenies validation for the proposed framework.

Table 7.2 CD participants for framework validation

Interviewee	Role	Aim
CD1	Director	Estimate the feasibility and workability of the proposed framework
CD2	Head of Research and Development	Establish the BIM maturity level and its relationship with sustainable development

CD3	Department Manager	Examine all components of the proposed framework and their compliance within company regulations
CD4	Project Manager	Estimate the accuracy of the framework and the impact of the components on sustainable development

7.3.2 Validating the Components

The proposed theoretical framework can be broken down into seven components which are the economic, social, and environmental barriers, the BIM tools, and the economic, social, and environmental sustainability development outcomes. Interviewees were asked to share their ideas on these components to verify the accuracy of the results. The validity is based on the participants agreement on the components which were descried as the barriers of BIM implementation, the BIM tools and attributes, and finally the green attributes or sustainability factors. Every interviewee had full access to the proposed framework and the method it was developed, in order to guarantee that the participants are fully aware of the implementation process.

7.3.2.1 Validity of Economic Barriers

All participants agree that economic barriers are the main concern when it comes to the BIM implementation process. The reason behind prioritizing BIM economic barriers is due to the dependency of the economic sector on the construction industry. As a result, clients and company directors find it difficult and challenging to invest in BIM when the whole construction industry does not generate enough profits to do so. Participants agree that the initial high cost of BIM along with the high costs that come afterwards such as training and education, present a challenging and uncertain environment for BIM adoption. The reason is that the construction sector in Lebanon is a risky investment, as a result, there is no guarantee for any returns on investment. As stated by the interviews, every company allocated a certain budget for research and development, unfortunately, due to Lebanon's unstable economic state the allocation of funds for research and development has dropped tragically. All participants agree that taking a risk with BIM implementation is not

a wise decision in such unstable economy, knowing that the employees themselves are not yet capable of taking on such responsibility. Moreover, the employees that are capable on working with BIM tend to be an economic burden not an asset for the company. All participants agree that the economic barriers featured in this framework are a good front for any technological advancement that is being held back due to lack of funding and financial investment.

7.3.2.2 Validity of Social Barriers

All participants agree that social barriers are the most overlook form of limitations that have failed BIM implementation in the Lebanese construction industry. Participants agree that mentality and attitude is the main initiative for any development in the construction or any other sector. However, when it comes to the construction sector, the attitude towards change does not exist. The economic barriers refer to the means in which companies can achieve the goal, however the social barriers show that people who work in the Lebanese construction sector, do not have the motive to set a goal to be achieved. Being content with delivering the same product at the same quality and effort has been the downfall of technological development in the construction sector. Moreover, BIM requires a learning process which the companies in Lebanon cannot offer for its employees, as a result, the employees find it more difficult to go on their own and acquire such knowledge, a knowledge which is already missing from the Lebanese construction sector. The reason behind this lack of knowledge, is due to the lack of awareness on the benefits of BIM in the construction sector, along with lack of research and study, and a complete denial by higher education institutions, all these factors have contributed to the low levels of awareness and knowledge of BIM in the construction sector. All participants agree that social barriers are an external form of limitation, which is not controlled by the company itself, yet has a large impact on the sector. As a result, the social barriers presented in this framework summarize all socially related factors that hinder the development for BIM in the construction sector.

7.3.2.3 Validity of Environmental Barriers

All participants agree that environmental barriers are supplementary limitations for the low BIM implementation levels. The reason for such classification is summarized in the

proposed framework and all interviewees agree that environmental concern is not that main objective for the construction sector in Lebanon. Participants agree that environmental regulation have been overlooked by the government, clients, and directors and as a result, have led to this environmental deterioration. Programs have taken on the initiative of mending the environmental fence, however, in construction it's a long and imminent process. When it comes to BIM adoption, the lack of knowledge, standardization, and sustainability standards made no use for BIM involvement in the construction process. BIM is high technology advancement with no beneficial use in sustainable construction due to the lack of demand. When sustainable construction becomes mandatory by the government or client, BIM will have a larger demand in the market as a tool in capable of achieving such designs. Unfortunately, at the moment environmental barriers presented in this framework, are a clear example of why BIM is not being used as a tool for sustainable construction.

7.3.2.4 Validity of BIM Tools

All participants agree that the BIM tools presented in this theoretical framework are the main tools construction companies in Lebanon are attempting to acquire through BIM implementation. BIM maturity, even though a relatively vague concept, defines the level in which BIM is operating in the construction sector. In Lebanon, all interviewees agreed that BIM is still in its low levels of maturity, so not all BIM tools have been considered for adoption as of today. Nevertheless, the BIM tools presented in the framework are the tools that construction companies are attempting to implement. All participants agree that in order to mitigate the barriers, BIM tools should be acquired as a way of eliminating the limitations and consider further development.

CC have adopted some of the BIM tools stated in the framework such as visualization, design coordination, integrated site layout, scheduling estimations, and information management. Based on their experience, BIM has shown great potential for improving the construction process, unfortunately, since BIM is still new, there predictions of BIM capabilities are still limited. As a result, participants in CC agreed that BIM has become a priority in their construction process and they will continue on adoption more BIM tools, but unless there is a dramatic change in the demand for BIM based projects, the adoption

of more BIM tools will remain a slow progress. Participants in CC believe that BIM has become a building block for any construction company, and the tools presented in this framework should be adopted in every construction company in the Lebanese sector. The inability to acquire such tool is an example of the slow-moving rate of the Lebanese construction sector. Companies who do not have such tools, cannot be regarded as a high achieving construction company. Hence, CD agreed that BIM tools have been a growing concept in the Lebanese market, and therefore CD has set a plan in motion to adopt BIM tools in its future projects.

As a rising company in the Lebanese market, CD considered the proposed framework as a guide for BIM implementation. The tools present is this framework are the tools needed for meeting the required demand of the market. Construction project in Lebanon today have become more complex and challenging, and thus small to medium companies cannot carry out the required tasks as planned. Larger companies who are not familiar with BIM are struggling to keep with market demand, and CD is an example of such company. CD has considered the barriers presented in this framework as obstacles that need to be removed in order to begin the BIM implementation process. As of today, CD is attempting to acquire the basic BIM tools such as visualization before moving on to more challenging acquisitions.

All participants agree that BIM tools are the necessary attributes needed to lower the impact of the BIM barriers, and are the first step for a more sustainable construction sector.

7.3.2.5 Validity of Economic Sustainability

All participants agree on the importance of achieving economic sustainability. The loss of financial resources due to lack of good management, design, and construction has been an issue in the Lebanese construction sector for some time. Achieving economic sustainability is a priority according to all the interviewees. All participants agree that following proposed framework helps create a map for reducing costs and effectivity manage financial resources in a given company. CC stated that since adopting BIM visualization tools in construction projects, clients have been capable to take cost effective decisions. BIM visualization tools aid clients in visually experiencing the

construction process and therefore could select more suitable material which cost less and lasts longer. Using analysis and simulations, CC was able to prepare more accurate designs and therefore eliminate uncertainties at the beginning of the project for improved outcome.

From a perspective of a company that has not experienced BIM benefits yet, the validity is based on what is the desired outcome. Therefore CD, has set similar goals, in terms of economic improvement, as the ones stated in the proposed framework. Attempting to lower cost whilst improving other aspects of the construction process, is a fiscal challenge, yet with the proper utilization of BIM tools, construction companies attempting to adopt BIM, have set a preliminary target of achievement to improve economic sustainability. CD has overcome the barrier of investing in BIM tools, and have set a plan in motion to adopt visual BIM tools and create unified platforms to improve communication and collaboration between project participants, aiming to eliminate extra costs due to errors while improving the construction material selection process.

All participants agree that economic sustainability is a difficult component to achieve, yet it is the most critical one, as majority of decisions are taken based on money and financial capabilities. It is difficult to keep money in rotation when there are so many barriers attempting to break the cycle. Nevertheless, companies are starting to appreciate BIM more and are taking on the risk of adopting BIM as a critical part of the construction process.

7.3.2.6 Validity of Social Sustainability

All participants agree that achieving social sustainability is difficult due to the company's inability to control external factors, such as education, awareness, and knowledge. According to company CC, achieving social sustainability involves educating a higher number of employees about the use of BIM tools. Unfortunately, not all participants enjoy taking part, yet the company has set an initiative of informing the participants about the benefits of BIM in terms of work environment. According to CC, the social sustainability components presented in this framework, are the benefits they supply their workers to push employee's involvement in BIM. Improving worker productivity requires an incentive to motivate the work force to push the barriers and take on more responsibility in the

company. CC was witnessed an improvement in client satisfaction since adopting BIM tools in their construction process. Social sustainably requires understanding what people want from a project and the ability to deliver it, therefore, CC uses the available BIM tools with the proper team to be assigned to the appropriate project. In order to push employees to extend their knowledge on BIM, CC assigns BIM experts for high profile projects, as a result inspiring employee to seek BIM knowledge for further development, and therefore building a reputation on the importance of the knowledge and awareness of BIM in the construction sector.

On the other hand, to test the validity of BIM on social sustainability, CD enrolment program considers new employees with experience with BIM tools such as visualization and simulation to create more sustainable project designs. As a result, CD is improving the company profile and pushing clients for more BIM based project. As a result, CD has become a more socially active company, with higher insight on client demands whether internal or external.

All participants agree that social sustainability creates a better environment of work. Even though, the market does not regard social sustainability as a primary accomplishment, companies have realized that BIM adoption could help improve social sustainability whose impact goes beyond expected and is capable of creating the atmosphere required for pushing the construction sector in Lebanon to the next level.

7.3.2.7 Validity of Environmental Sustainability

All participants agree that lack of environmental sustainability has created harsh environmental circumstances due to the environmental barriers presented in this framework. According to CC, achieving environmental sustainability requires advanced BIM tools that clients find irrelevant for their projects. However, CC has taken into consideration the growing field of sustainable construction and hopes to be a pioneering company from that perspective. The lack of environmental sustainability is due to the lack of BIM tools according to the interviews. Since environmental sustainability is an advanced issue it can only be mitigated using advanced tools for design and construction. All participants agree the in order to achieve environmental sustainability all components

presented in the framework are the baseline of achievement. In other words, following the path of adopting the proper tools will help achieve the design sustainable outcome.

The participants in CD agree that adopting BIM tools is the key for achieving environmental l sustainability through analysis and simulation. Therefore, CD has taken an initiative of introducing sustainable design models. Unfortunately, the barriers limit executing these designs on a global scale, however, from design perspective BIM tools have created the necessary models of energy analysis simplifying the choice of sustainable material whilst creating a visual representation of the construction process lowering the energy consumption required to maintain project performance.

BIM's environmental sustainability capability cannot be fully comprehended at the moment; however, all participants agree that combination of BIM tools and environmental sustainability components could unlock the potential of delivering green sustainable projects.

7.3.3 Recommendations on the Proposed Framework

After reviewing the participants comments on the proposed theoretical framework, which interviewees were asked to share based on their validation, all participants agree that the components in the framework are suitable for practice. However, comparing CC, a company which has experienced working on BIM-based projects, with CD, a company which is recently looking to adopt BIM in their construction process, it was clear that BIM maturity plays a very influential role on the company's capability to adopt BIM. The following summarizes the components of the proposed framework with respect to its classification within the initial implementation phase.

Table 7.3 Framework Components Classification

Interviewee	Classification
Economic Barriers	• Primary limitations of BIM implementation in the Lebanese construction sector. • Directly related to the company and the project.
Social Barriers	• External limitations of BIM implementation.

	• Involves external factors such as society and education in the construction project.
Environmental Barriers	• Supplementary limitation of BIM implementation. • Non prioritized by the clients, hence the low demand
BIM Tools	• Early stage of BIM adoption tools such as visualization and information management tools • Forward stage of BIM implementation such as energy simulations and MEP system modelling
Economic Sustainability	• Main target for construction companies • Primary objective
Social Sustainability	• Requires external factors • Works beyond the construction project
Environmental Sustainability	• Cannot be achieved without the necessary BIM tools • Long term objective

7.4 Chapter Summary

This chapter presents the proposed theoretical framework that resulted from the data analysis. The chapter explains and shows the rationality behind the proposed framework. In addition, this chapter validates the proposed framework based on interviews carried out in two companies that are recently adopting BIM and examined its use in sustainable construction.

Chapter VIII: Conclusion

8.1 Chapter Overview

The following chapter will present the conclusions of this research by confirming that the aim and objectives have been met, as well as, answering the research questions presented in chapter 1. This chapter will highlight the findings of this research and the contribution to knowledge, as well as, discuss the limitations faced when conducting this research. Finally, this chapter will provide a recommendation for the direction of future work on the subject of BIM and sustainable construction in the Lebanese construction industry.

8.2 Achievement of Research Aim and Objectives

The aim of this research is to develop a theoretical framework for the successful implementation of Building Information Modelling (BIM) and explore its impact on Sustainable Development in the Lebanese construction industry. There are four supplementary objectives associated with the research aim stated in section 1.5. The following sections will summarize the information gathered throughout the research and provide the necessary evidence showing the completion of the objective to finally meet the aim of the research.

8.2.1 Achieving the Aim and Objectives

The objectives are set as milestones for achieving the aim of the research. Therefore, this section will discuss the methods that were used to meet the objectives of the research and verify realising the aim.

Objective 1: Identify the major contributors of the Lebanese construction sector prompting the need for sustainable development and analyse their sustainable impact.

The first objective was achieved by reviewing the relevant literature related to sustainable development in Lebanon. Chapter 3 shows that Lebanese construction sector has been underperforming when it comes to sustainability, and as a result, has led to harsh consequences in terms of natural resources, finances, and living standards. The purpose of this objective is to establish the need to study sustainable development in the Lebanon

and establish a relationship between Lebanon's sustainability performance and the construction industry. Chapter 3 discuss Lebanon's perspective on sustainable development, and based on the literature provided, Lebanon has overlooked the importance of sustainable construction and therefore have witnessed negative economic, social, and environmental impacts that have diminished the Lebanese economy, while the population and construction projects continue to rise with no control over the consequences. Section 3.2 discusses the negative impacts that Lebanon has been facing due to low sustainability performance, and therefore establishing the major contributors for the need for sustainable development in the construction industry. In later stages, section 5.5.7 analyses the impact of these contributing factors on sustainable development, which can be later on mitigated by implementing BIM in the construction industry. The major contributors for sustainable development in the Lebanese construction industry, have been built by neglecting the importance sustainable construction and the importance of technological advancement, therefore inspiring the need to investigate BIM in sustainable development.

Objective 2: Examine different BIM attributes and their limitations that can be used as tools in sustainable construction.

The study of previous literature stated the presences of BIM attributes which are BIM tools that can aid in achieving high quality designs and managerial execution, yet limited research shows these attributes used in the Lebanese construction sector. Chapter 2 section 2.3, introduced BIM by stating the benefits and barriers that limit BIM implementation, which inspired a closer look of BIM and sustainable development in section 2.4. Section 2.4 used previous literature to describe different BIM attributes in addition to Green attributes and create a unified link between the two concepts. This examination of BIM and green attributes set the stage for the data collection in an attempt to uncover the BIM tools used in the Lebanese construction industry, with the purpose of achieving sustainable growth. In section 5.5 the analysis shows a breakdown of the BIM benefits, barriers, CSFs, and sustainable implications, which were later on developed in sections 6.2, 6.2 and 6.4 of the discussion chapter, to finally create the components used in developing the theoretical framework.

Objective 3: Explore the Critical Success Factors of BIM that impact social, economic, and environmental sustainability.

Critical Success Factors are the key area of study for the implementation of BIM in the Lebanese construction sector. However, several research attempt to examine the CSFs of BIM implementation presented in section 2.3.4, and based on the information provided from previous literature, the data collection process focused on extracting the highest possible level of available information. The results are present for every case study and presented in section 5.4, which was later on used to identify the cumulative CSFs in Lebanon and divided in section 5.5.5 into 5 categories of human, industry, project, process, and resource factors. In chapter 6, the CSFs presented in this research were compared with CSFs provided by previous literature, and the comparison shows a high similarity, as a result and based on that information provided by that comparison sustainability could be broken down to its pillar of social, economic, and environmental aspects, where every CSF could influence the outcome of that sustainability pillar. These factors and their categorization into sustainability pillar were later on used to develop the theoretical framework proposed in this research.

Objective 4: Develop a framework for the successful implementation of BIM in the Lebanese construction industry.

After an extensive research based on qualitative data provided through interviews on the Lebanese construction industry, along with the use of BIM tools and achieving sustainable development, the proposed theoretical framework in section 7.2 has been divided into seven components. The economic, social, and environmental barriers, that explain the lack of BIM use in the Lebanese construction industry, along with the BIM tools, which provide an explanation on available technology that can be adopted and used to achieve the desired outcome, and finally the economic, social, environmental sustainability outcome, that can be expected from using BIM tools to eliminate the barriers and close the gap between construction and sustainable development. The proposed framework summarizes the contributing factors that can aid in implementation BIM and the expected sustainable outcome in the Lebanese construction industry.

Objective 5: Validate the BIM framework and its impact on sustainable construction.

In section 7.3, two construction companies were introduced as participants to validate the proposed theoretical framework. Section 7.3.1 introduces the participants, their role, and the aim of the interview. As a result, majority of the interviewees agree on the components of the proposed theoretical and method used to establish the them. The validity shows that the theoretical framework cover most of the aspect these companies are attempting to address and mitigate to implement BIM in their company, as well as, the desired outcome from the implementation process. As a result, the proposed theoretical framework matches with the strategy used by companies in Lebanon to implement BIM and goes beyond improving the scope of a project in terms of time, cost, and quality but focuses on introducing the concept of sustainable construction. Finally, section 7.3.3, highlights some recommendations by the validation participants for the proposed framework on every component involved to further improve the implementation process of BIM in sustainable construction.

8.2.2 Research Questions

After extensive research, as well as, achieving the aim and objective of this research, this section will attempt to answer the research question asked in the beginning of this research, in order to insure that this research has covered all aspects of understanding the process of achieving the desired aim.

Question 1: What role does BIM play in the Lebanese construction industry today, and how revolutionary is it considered to be in sustainable development?

This questioned was based on the understanding and willingness of the Lebanese construction industry to adopt BIM as a new technological innovation in construction projects. Previous research has shown that BIM is capable of enhancing the performance of the construction sector. Furthermore, several researches attempted to link the use of BIM with sustainable development. However, attempting to work with BIM in Lebanon, requires understanding of the current construction performance, and more specifically the understanding of the construction industry on the importance of technological advancements in the sector. Therefore, this question was used as a baseline to establish

the knowledge and awareness levels of the Lebanese construction sector on the use of BIM. Chapter 3 of this research examined the use of BIM in Lebanon, where previous research shows that BIM has been rarely used in Lebanese construction projects. The interviews conducted as part of this research, also show that BIM's understanding has not been fully established in Lebanese construction companies, thus with limited knowledge there is limited potential. As a result, the low use of BIM and the little knowledge available shows that the Lebanese construction industry did not value BIM as a technological advancement, as such limiting its potential to achieve sustainable growth.

Question 2: How does BIM adoption impact social, economic, and environmental sustainability in Lebanon?

The BIM barriers have limited the adoption of BIM in the Lebanese construction industry, however, the growing involvement of project participants with BIM has somehow excited the adoption of BIM rate. As a result, project participants have looked beyond these barriers and examined the benefits of BIM in the construction sector. This has led to investigating BIM to achieve a higher quality of construction. Even though, as of today, the project owners remain invested in improving the scheduling and cost estimation process, BIM has presented the potential of achieving a more sustainable process of construction. After examining the impact of BIM on sustainable development, the suggested framework shows that BIM tools could help achieve social, economic, and environmental sustainability by improving human performance, reducing errors, and provide new methods of design and management to provide more sustainable alternatives.

Question 3: What are the barriers and limitations preventing the successful implementation of BIM in Lebanon?

Previous literature presented in section 2.3.3, discuss the different barriers and limitations that have been restricting BIM implementation, nevertheless, for the accuracy and credibility of the research an investigation into the barriers of BIM, in the Lebanese construction industry, was carried out and presented in sections 5.4 and 5.5. At that stage, barriers could be divided into three major categories economic, social, and environmental. The main economic barriers could be summarized in the lack of investment in

technological advancements such as BIM tools, while social barriers could be summarized by the reluctance to change the existing construction process due to low levels of awareness and knowledge of BIM, and finally environmental barriers could be summarized by lack of standardization and initiative towards sustainable development. Several other barriers could be presented in this research and in section 6.2, the literature presented in recent research complements the barriers found in the suggested framework. The purpose of understanding the barriers and limitations is to develop a mitigation plan to prevent holding BIM from being implemented in the Lebanese construction industry.

Question 4: What are the critical success factors that need to be considered when developing a framework for the successful implementation of BIM in the Lebanese construction sector?

Since CSFs are the most crucial elements of BIM implementation, identifying these factors will set the stage for a successful BIM framework of implementation. From previous literature, there are several CSFs that dictate BIM's performance in the construction industry, yet CSFs have not been clearly established in Lebanon to facilitate BIM's incorporation. The findings of this research show that CSFs can be divided into five categories, and these categories are based on mitigating the barriers limiting BIM implementation as shown in sections 5.5.5 and 5.5.6. In chapter 6, previous literature presents different CSFs based on previous BIM studies, yet comparing this information with the ones gathered in this study, many similarities are presented, and therefore, BIM implementation can follow a standard process as the one used to establish the framework in chapter 7.

8.3 Research Conclusion

The following conclusion can be drawn from this research. First, BIM can be introduced as a revolutionary technology that can change the construction industry, however, very few countries have begun to implement it and use its full capabilities. Lebanon, a developing country, has yet maximize BIM's potential in the construction industry. Many barriers limit the adoption of BIM in the construction industry, thus rendering the Lebanese construction industry stagnant and incapable of growth. The low performance levels of

the Lebanese construction sector have led to severe negative consequences from sustainable perspective, as a result, the growing population and over urbanization have over-used the available natural resources and destroyed the Lebanese environment. As a result, urging the need for change and adoption of new technology.

From previous literature, BIM shows promise when introduced in sustainable construction. This researched aimed to develop a strategy to implement BIM and explore its influence of sustainable construction. Three companies were involved in the data collection process for this research, in which seven themes were discussed to investigate the BIM knowledge and experience. The seven BIM themes highlighted the BIM definition, role, benefits, barriers, CSFs, potential for change, and sustainability development. Based on this information, the analysis shows that BIM in the Lebanese construction industry, is still very primitive and people have little knowledge about the subject. In addition, companies also have limited knowledge on sustainable development, hence the low demand for BIM in construction projects.

The findings show that BIM barriers are a result of economic, social, and environmental issues which limit the implementation of BIM in the construction sector. This limitation, in return, dictates the outcome of the project. Sustainability can be divided based on its pillars of economic, social, and environmental sustainability. The fact that BIM barriers and sustainability pillar operate under the same categorization was used to introduce BIM tools that can limit the barriers and impact the sustainable outcome.

As a result, the research identified seven main components for the proposed framework of BIM implementation, after examining the CSFs that can aid the adoption of BIM in the construction industry, based on participant knowledge and experience with BIM in Lebanon.

Finally, the categorization of the BIM barriers, based on the information gathered throughout this search, aided in developing a framework of the successful implementation of BIM, and based on the responses provided during the validation process, the proposed framework shows promising result in terms of sustainability and the growth of sustainable construction in Lebanon.

8.4 Contribution to Knowledge

The contribution to knowledge can be divided into two parts, the theoretical contribution and the practical one.

8.4.1 Theoretical Contribution

The theoretical contribution highlights the key terms and concepts used in this research. BIM is a relatively new concept in Lebanon with limited research and knowledge about the topic, and the same can be said about sustainable development. Considering a research that joins the two topics together requires a thorough examination of the two topics.

The theoretical contribution focuses on increasing the knowledge of BIM and sustainable construction, hence highlighting the definitions of the terms and exposing the importance of addressing the issues related to the BIM barriers and negative consequence that result from lack of sustainable planning.

From a theoretical perspective, the research explains the definition of BIM, as well as, examines the role, benefits, and barriers of the topic in the Lebanese construction industry, which based on the existing literature, is very limited. The research shows the relation between BIM and sustainable construction in terms of technological advancement, which are currently missing in the Lebanese construction industry, thus prompting the need for further understanding and development on the concepts of BIM attributes and Green attributes.

The findings presented in this research, propose a theoretical framework for BIM implementation, which based on the research and validity, can limit the barriers of BIM and achieve sustainable construction. The framework developed a link between the BIM barriers, the BIM tools, and sustainable construction, which companies could consider when implementing BIM in the construction industry.

The significance of this research on theoretical knowledge is that it combines the little knowledge existing on BIM in the Lebanese construction industry, and the importance of achieving sustainable construction through a proposed theoretical framework of BIM implementation.

8.4.2 Practical Contribution

The practical contribution focuses more on the adoption of BIM for sustainable construction in Lebanon. Therefore, the research highlights the BIM tools that are currently being used by construction companies and discusses the BIM maturity levels for future development. The findings show different perspectives based on different levels of project participants and provides the experience of project members with BIM and sustainable construction.

The categorization of Critical Success Factors was the building block used to understand the use of BIM tools in the construction sector. The research identifies five categories of CSFs, which are used to adopt BIM. The distribution of BIM barriers into economic, social, and environmental barriers gives a practical understanding BIM's current operating levels.

The research shows that BIM capabilities can generate a new process of construction, focusing on improving the managerial environment, thus providing a new outlook on the construction process. In addition, the finding show that BIM adoption will improve the quality of design and execution which is directly linked to achieving a form of sustainable construction. The expected BIM benefits are starting to become clear in the Lebanese construction industry, as there is an increase for BIM-based projects on Lebanon.

The proposed framework draws a relation between BIM and sustainable construction, by identifying the barriers, tools, and outcomes. The research has highlighted the criteria necessary for the successful implementation of BIM.

Based on the validation process, the sustainable outcome remains theoretical at the moment, but the BIM barriers and BIM tools have given a new practical role for many of the directors, managers, designers, and contractors.

The current state of BIM knowledge requires further development and a more hands-on strategy for implementation, which based on the findings in this research, were used to develop the practical tools for the development of the framework.

8.5 Research Limitation

The research aimed on developing a framework for the successful implementation of BIM to achieve sustainable construction in the Lebanese industry. Unfortunately, the research faced various challenges and limitations.

A challenging aspect of the research was the limited research on BIM in the Lebanese construction industry. Due to the primitive nature of the Lebanese construction industry, as well as, the low levels of awareness on BIM, carrying out this research presented limited studies on BIM in the Lebanese construction industry. Therefore, investigating BIM in Lebanon relayed on studying countries with similar conditions to produce the literature review.

The same could be said about sustainable development. Limited knowledge and practice of sustainability made this research limited on the relation between BIM and sustainable construction. The lack of previous research limited the ability to compare the findings of this research with previous studies, therefore limiting the outcome.

Another limitation was the lack of BIM experts in the Lebanese construction industry, which presented a challenge when undergoing the data collection process. Even though the interviewees in this research have some knowledge and experience with BIM very few could be referred to as experts in BIM and sustainability. The idea that Lebanon still struggles to implement BIM, made it challenging to incorporate the study of BIM and sustainability together.

Understanding the CSFs was based on participants experience with BIM rather than knowledge, thus the proposed framework is a generalization of the BIM implementation process. In addition, this framework is based on internal factors, where the interviewees are participants in the Lebanese construction industry, with a limited view of external factors, thus showing some weakness in the study.

Finally, the validation process is limited to two companies initiating the BIM implementation process, and due to long and complicated nature of this process, the validation was restricted to a short time frame, thus restricting the conclusion of the proposed framework and this research.

8.6 Recommendation and Future Direction

The Lebanese construction industry have recently begun the BIM implementation process. Many factors limit BIM's proper implementation, and many unknowns and variables remain a challenging aspect of BIM. Sustainable construction is the future of the industry, and companies worldwide are pushing the use of BIM. Nevertheless, in every industry there are challenges, barriers, and limitation which will hinder the use of technology.

The Lebanese construction industry is growing, and thus raising the standards of construction, so it is at this point that industry should improve its overall performance. Thus, future research should further examine the implementation of BIM in the construction sector. This research focused understanding BIM and develop a relationship with sustainable construction in a qualitative research approach. Future research might consider a quantitative research method to quantify the BIM the rate of successful BIM implementation and BIM use in the construction industry.

This research shows that there is a relation between BIM and sustainable construction, where there are many factors that contribute to improving the sustainability aspect of the construction industry by introducing BIM in the construction management process. Future research could further investigate the internal and external factors that could further improve sustainable construction and focus more on the BIM tools that could aid in doing so.

Finally, a research for introducing BIM on Lebanese higher education could further raise the knowledge and awareness levels of BIM, as well as, train future generations to work with BIM and achieve better quality, since one of the key barriers found in this research is the limited knowledge and awareness levels of BIM and sustainability. A research that could highlight this fact and focus on minimizing its impact, could show great potential in future research.

8.7 Chapter Summary

This chapter summarizes the thesis and provides a general overview of achieving the aim and objectives. This chapter demonstrates the final outcome of this research by

answering the research questions and highlighting the expected contribution from a theoretical and practical perspective. Furthermore, this chapter discuss the limitation faced when conducting this research and provides a fresh perspective on new and innovative studies that could be used to further develop this topic and develop future research on BIM and sustainable construction. This chapter is an overall conclusion for this research highlighting the necessary achievements and limitation faced to develop the proposed framework for the successful implementation of BIM in sustainable construction.

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